POWER PLANT ENGINEERING

Established Over 30 Years

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Contents of this Issue

Page

Power, Light and Heat for the Morton Hotel. Illustrated..300

Electric Power Development in the Chicago District. By William S. Monroe. Illustrated.....305

Engine Room Signals 310

Machine Control and Regulation of Combustion. By J. F. Shadgen. Illustrated 311

Furnace Design for Traveling Grate Stokers. By H. S. Colby Illustrated 313

Steam Tables Developed from Harvard Experiments.....316

British and European Semi-Diesel Engines. By F. Johnstone-Taylor. Illustrated 317

Transmission and Distribution Lines III. By Stephen Q. Hayes. Illustrated 321

Illumination Design for Turbine Rooms. By Davis H. Tuck. Illustrated 325

Essentials of Correct Boiler Water Conditioning. By Dr. R. E. Hall. Illustrated.....327

Public Utilities Use Nearly 1½ T. of Coal a Second in 1925. Illustrated 331

Montana Power Co. Completes Mystic Lake Plant. By A. D. Stewart and M. E. Buck. Illustrated.....332

Suggestions for Improving Ice Plant Operation.....334

System Load Curve Affects Motor-Driven Ice Plants.....335

Efficiency Characteristic of Baffle Type Steam Purifier. By Grant D. Bradshaw. Illustrated.....336

Letters Direct from the Plant: Vacuum System Gives Steady Water Flow. Dashpot Assisted by Spring. Oil Engines Often Solve Power Problems. Illustrated.....337

Questions and Answers: Study These Indicator Diagrams. Chimney Load Determined by Variable Factors. Increased Horsepower with Higher Frequency. Heating Water in an Open Heater. Relation of CO_2 to Flue Gas Temperature. Illustrated 339

Editorial Comment: Calling in the Doctor. Engineers' Contribution to Conservation. Getting at the Cause of Our Educational Troubles. Power and Profits Have Become Dovetailed 342

Electrical Engineers Discuss Many Topics.....344

Ammeter, Voltmeter and Ohmmeter Combined in One Instrument 346

Louis Allis Direct-Current Motors. Illustrated.....346

Automatic Change-Over Switch Insures Continuity of Service. Illustrated 347

Float Actuates Ball Seat Steam Trap. Illustrated.....347

A. S. S. E. Holds Fourth Midwest Conference.....348

News Notes 348

Catalog Notes 350

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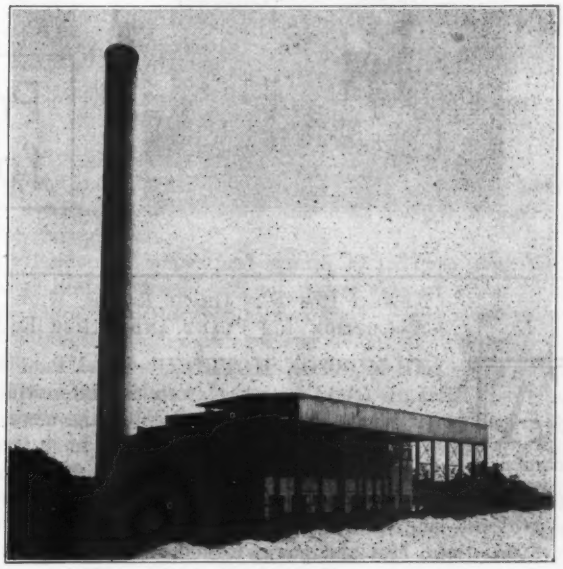


This Pump Has No Piston

PULLING GAS out of a partial vacuum and lifting it 200 ft. into the air is a real pumping job, yet here is a pump without a single moving part that works perfectly without the driving power of steam or electricity. Like real mechanical pumps, however, chimneys have their characteristics. At times they seem as temperamental as a much-married movie actress. The loads they will carry can be varied considerably but there are limitations, so chimneys must be properly designed in order to maintain the most desirable conditions.

Recently a reader of Power Plant Engineering was confronted with the problem of designing a chimney and requested assistance in its solution. In the Questions and Answers Department of this issue, those interested will find information necessary for solving similar problems. This answer, as well as others that appear in the Questions and Answers Department of every issue, was selected for its practical value to plant owners, managers and engineers.

Your problem today may not deal with chimneys, it may have to do with prime movers, boilers, heat exchange, combustion, electrical machinery, air compressors, refrigeration, in fact any phase of power plant engineering. All such problems may appropriately be discussed in that section of the magazine and it is there that the power plant owner or operator not only may learn of the problems confronting others but often may find opportunity of establishing beneficial contact with those having similar troubles.

Power, Light and Heat for the Morton Hotel

NEWEST HOTEL IN GRAND RAPIDS, MICH., HAS THREE ENGINE-DRIVEN GENERATORS, ABSORPTION ICE PLANT AND OTHER EQUIPMENT FOR SERVICE TO 400 GUEST ROOMS

AT THE MORTON HOTEL IN Grand Rapids, Mich., is found a most complete and interesting power plant. The Morton Hotel is the newest in Grand Rapids and incorporated in it are many refinements of design and construction. The illustrations above show the exterior of the hotel and part of the main lobby. The Morton Hotel power plant furnishes light, heat and power to 400 guest rooms, dining and banquet rooms and the like, and in addition supplies drinking water, compressed air, refrigeration and ice and all the varied services demanded by a modern hotel. About one-quarter of the ground floor space is occupied by the Kent State Bank, which buys light, heat and power from the hotel plant, but no data are available on the bank equipment.

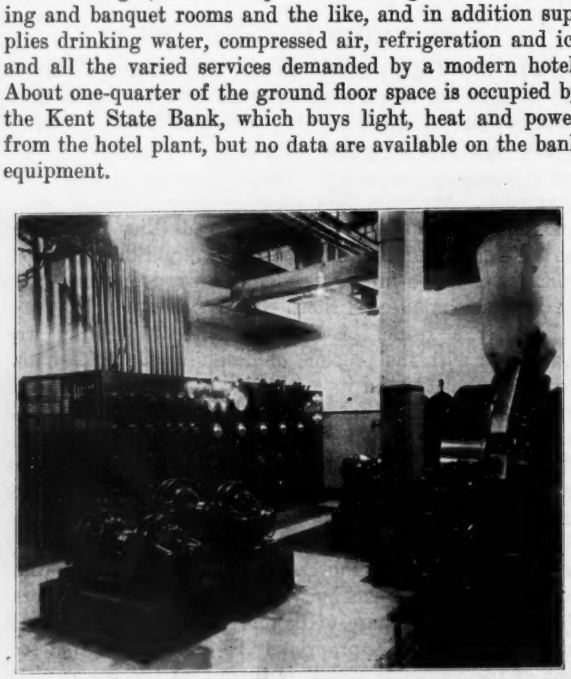


FIG. 1. SWITCHBOARD CONTROLS THREE-WIRE HOUSE DISTRIBUTION SYSTEM, WHICH USES BALANCER SETS ON NEUTRAL

Exhaust steam is furnished for 60,000 sq. ft. of radiation in the hotel building during the heating season. Typical requirements for high pressure steam are about 8500 to 9000 lb. steam for the kitchen per 15-hr. day and between 9000 and 10,000 lb. of steam for the service water heaters for a 24-hr. period. Steam consumption for the absorption type refrigeration plant is about 35 lb. per hr. per ton of refrigeration.

Data obtained in the summer of 1924, after the plant had been operating a short time, are given below and give some idea of the services the plant must render.

Water Temp.	Ice Plant Quantity Cu. Ft. 24 hr.	Steam Pres.
50 deg.	10,800	2½ lb.
73 deg.	24,000	2½ lb.
78 deg.	29,800	18 lb.

The 2½ lb. steam is exhaust; the 18 lb. steam is high pressure and for a 24 hr. run, 68,500 lb. of steam were used as measured by a flow meter. Brine temp. is 7 deg. out and 15 deg. in; water was metered at coils.

The increased cost between 50 deg. and 78 deg. temperature of water is:

Water @ 7c per C	$13.30
Coal 1½ t. @ $5.40	8.10
Boiler Water	3.32
Total	$24.72 per day
Cost of plant at 50 deg. Temp.	$ 7.56 per day

Under normal conditions, one boiler runs the plant, developing 170 hp. according to flow meter. The laundry uses 1198 lb. steam per hr. regardless of the house count (number of guests registered). This is about 39 hp. where 30 hp. was contemplated.

Total water used in house, exclusive of laundry, ice plant and boilers:

50 per cent house during heating season .....
.....11,778 cu. ft. per 24 hr.
50 per cent house non-heating season—water temp. 73 deg. .....13,486 cu. ft. per 24 hr.
50 per cent house non-heating season—water temp. 78 deg. .....15,189 cu. ft. per 24 hr.
100 per cent house non-heating season—water temp. 78 deg. .....27,480 cu. ft. per 24 hr.

Laundry Water per 24 hr.	Hot	Cold
50 per cent house	935 cu. ft.	374 cu. ft.
100 per cent house	1650 cu. ft.	657 cu. ft.

Coal costs $5.40 per ton delivered and the city water rate is 7c per hundred cu. ft. regardless of quantity.

Three 250-hp. Water-Tube Boilers Supply Steam

The power plant is located in the hotel basement, the arrangement being as shown in Fig. 5. The plant is divided into boiler room, engine room, refrigeration room, pump room and ash and coal storage rooms. In the boiler room are three Oil City water tube boilers of 2500 sq. ft. heating surface each. These are fired by Automatic Smokeless Furnaces which are side feed stokers, set in a dutch oven setting, as shown in Fig. 2. These are driven from a small steam engine by a front bar, shown extending across the stoker fronts. Ash from these boilers drops into ash pits below, from which it is loaded into wheelbarrows and taken to the ash storage room. It is removed from this room at suitable intervals by loading it into cans, which are hoisted to the ground level by a hand operated ash hoist.

Coal used at the Morton plant is Creach coal from Kentucky, averaging about 13,000 B.t.u. per lb. It is dumped from the ground level through chutes into the coal storage room, whence it is taken to the stoker hoppers in wheelbarrows and loaded by hand. About 225 t. of coal can be stored in the storage room.

Figure 2 shows the water columns and pressure gages with which each boiler is equipped. Steam is generated at 125 lb. gage although the boilers are designed for 150 lb. pressure. Feed water level is regulated by Copes feed water regulators, one of which can be seen in Fig. 2. In the boiler room are also placed the three hot-water heaters for general hotel hot water service, located overhead as shown in Fig. 5. Two of these are of 1500 gal. capacity and one is of 1000 gal. capacity. Water is heated in these by live steam, temperature of the water being controlled by Powers regulators.

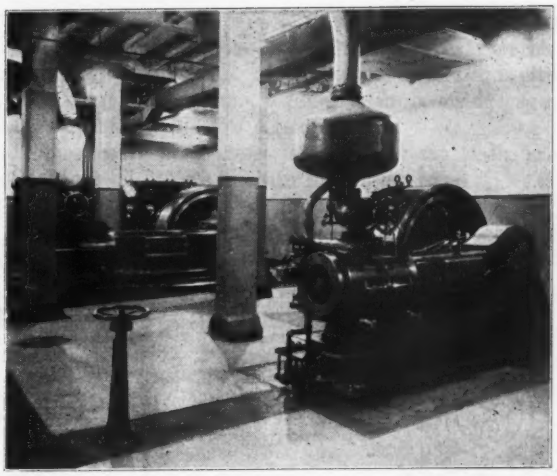


FIG. 3. THIS VIEW SHOWS TWO OF THE ENGINE DRIVEN GENERATORS

Beside the boiler feed pumps is an open type feed water heater rated at 900 hp., using exhaust steam from the engines. Boiler feed pumps are 7½ by 4½ by 10-in. Worthington duplex plunger steam pumps. Boiler blow-off lines lead through a trench behind the boilers to a blow-off tank, as shown in Fig. 5. Main steam leads from the boilers connect to a header about 10 ft. above the floor level and leads are taken from this header to the engines and high pressure lines in the plant. A runway under this header gives access to valves and piping. Position of boiler dampers is controlled by A-Jacks damper regulators.

Ridgway Four-Valve Engines Drive D.C. Generators

Three Ridgway engines with generators, two balancer sets and main switchboard and gage board occupy the engine room. These engines are of the single cylinder four-valve construction type. Number 1 engine is 20 in. by 26 in. and is rated at 412 hp. at 175 r.p.m. The other two are 16 in. by 18 in. engines rated at 232 hp. The engines

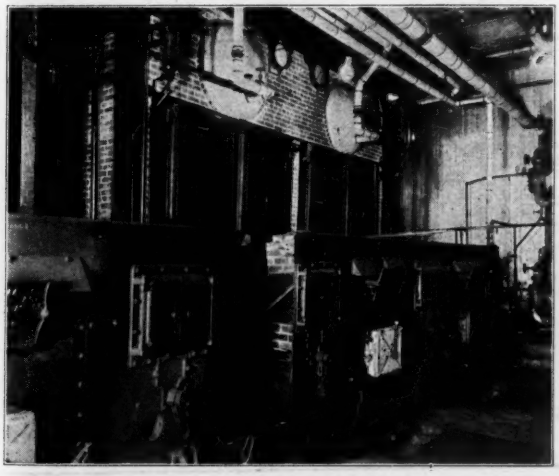


FIG. 2. STOKERS IN DUTCH OVEN SETTINGS FIRE 250-HP. WATER TUBE BOILERS

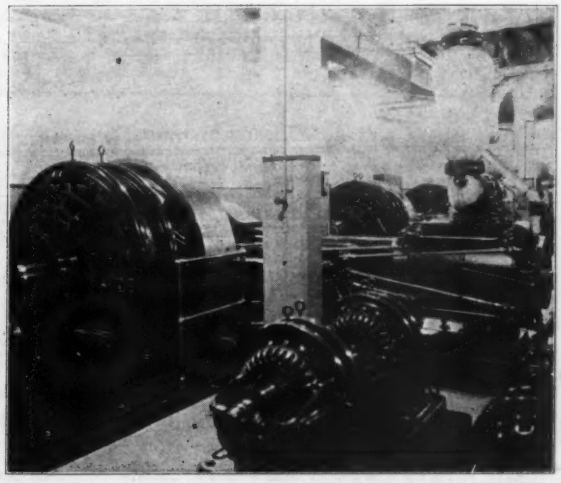


FIG. 4. THREE GENERATORS ARE DRIVEN BY FOUR-VALVE ENGINES

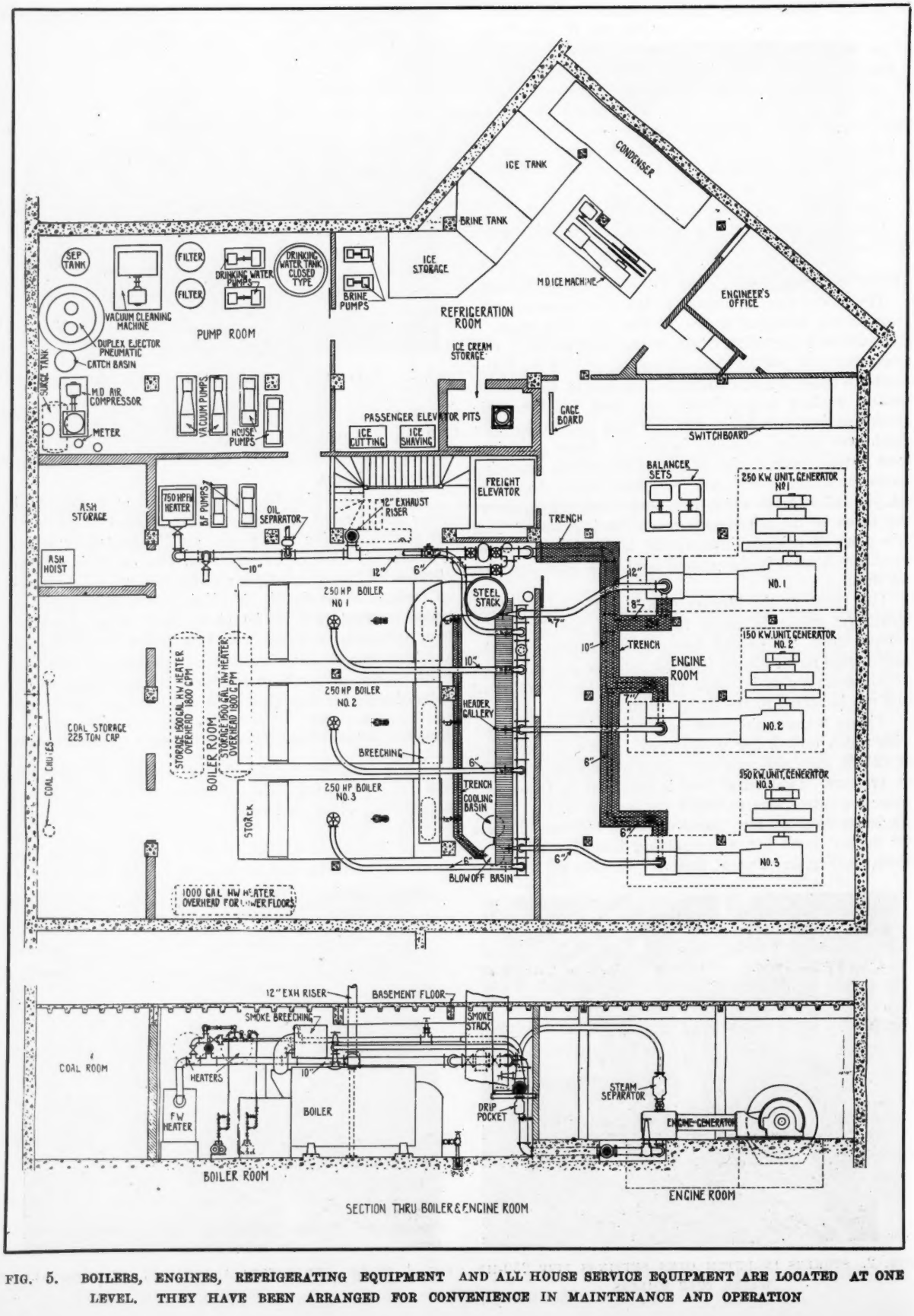


FIG. 5. BOILERS, ENGINES, REFRIGERATING EQUIPMENT AND ALL HOUSE SERVICE EQUIPMENT ARE LOCATED AT ONE LEVEL. THEY HAVE BEEN ARRANGED FOR CONVENIENCE IN MAINTENANCE AND OPERATION

are designed to develop the above ratings at a throttle pressure of 125 lb. gage.

Generators are all 230-v., d.c. machines, No. 1 being rated at 250 kw. and Nos. 2 and 3 at 150 kw. With various combinations of these units, almost any local conditions that may arise in the hotel can be met in the most economical manner. The electrical distribution system is of the three-wire type, with a split neutral employing balancer sets. There are two of these, as shown in Figs. 1 and 4, one set using two 6¼-kw., 115-v., 1200-r.p.m. machines, the other having two 3¾-kw., 115-v., 1500-r.p.m. machines.

Principal Equipment at the Morton Hotel, Grand Rapids, Mich.

Boilers, Stokers and Engines

3 Oil City Boiler Works water tube boilers; 2500 sq. ft. heating surface each; working pressure 125-lb. gage, designed for 150 lb.
3 Automatic Furnace Co. stokers, Model Automatic Smokeless Furnace type with front bar drive.
3 Ridgway Dynamo & Engine Co. reciprocating engines driving 230-v. d.c. generators. One 20-in. by 26-in. 412-hp., 175-r.p.m. Ridgway four-valve type steam engine drives 250 kw. direct-connected generator. Two 16-in. by 18-in., 232-hp., Ridgway four-valve type steam engines, each drive 150-kw. direct-connected generators. Throttle pressure, 125-lb. gage to develop above ratings.

Refrigeration Equipment

1 Carbondale Machine Co. absorption type ice plant, capacity 40 t. Absorption coils, 4 stands of 3-in. pipe, 6 pipes high.
1 Ice tank holding 40 cans of 300 lb. capacity each.
1 Condenser of 4 stands of 3-in. pipe, 20 ft. long, 8 pipes high. One exchanger, 18 pipes, 3-in. diameter. One rectifier of 4-in. pipe, 6 pipes. Generator 30 in. in diameter, 18 ft. long.
2 Carbondale Machine Co. ammonia pumps, 8 in. by 3¾ in. by 12 in., reciprocating duplex steam driven type.
1 Union Steam Pump Co. duplex plunger type brine-circulating pump, 7½ by 7½ by 6 in.
1 Union Steam Pump Co. centrifugal pump for auxiliary brine-circulating service, 130 g.p.m. capacity against 125-ft. head direct connected to Westinghouse Electric & Mfg. Co. Type SK, 10-hp., 230-v., 1700-r.p.m. d.c. motor.
1 Direct expansion type, 7-t. ice water cooler.
2 Buffalo Steam Pump Co. centrifugal pumps, cooler circulating, each 69 g.p.m. against 25-ft. head driven by Westinghouse E. & M. Co. 3-hp., 230-v., 1750-r.p.m. shunt-wound d.c. motors.

Pumps, Heaters and Miscellaneous Equipment

2 Worthington Pump & Machinery Corp. boiler feed pumps; duplex, plunger, steam-driven type; each 7½ by 4½ by 10 in.
2 Worthington Pump & Machinery Corp. cold water house pumps; duplex, plunger, steam-driven type; each 9 by 5¼ by 10 in.
2 Worthington Pump & Machinery Corp. duplex plunger type vacuum pumps for handling 60,000 sq. ft. of radiation in hotel heating system.
2 Yeomans Bros. Co. 150-g.p.m. sewage ejectors.
1 Spencer Turbine Cleaner Co. vacuum sweeper system.
2 Fisher Governor Co. pump governors on cold water house pumps.
4 Boylston Steam Specialties Co. pump governors, 2 on vacuum pumps, 2 on boiler feed pumps.
2 Worthington Pump & Machinery Corp. Laidlaw 8½-in. by 9-in. air compressors, belt-driven by 20-hp., 230-v., 1210-r.p.m. General Electric Co. d.c. motors.
1 Permutit Co. water softener, capacity 68,848 gal. per 24 hr. at 0 hardness.
1 Union Steam Pump Co. centrifugal booster pump in softener line; 150 g.p.m. against 90-ft. head, driven at 1750 r.p.m. by G. E. Co. 10-hp., 230-v. motor.
1 Well water pump, 8 by 10 by 12 in., duplex-plunger, steam-driven type, 300 g.p.m. with about 8-ft. suction lift.
4 Sims Co. water heaters, one for boiler feed water, three for laundry and kitchen.
Copes Boiler Feed Water Regulators.....Northern Equipment Co.
Traps and Separators.....Wright-Austin Co.
A-Jacks Damper Regulators.....National Regulator Co.
Powers Regulators on water heaters.....The Powers Regulator Co.
Water Columns.....The Reliance Gauge Column Co.
Steam and Water Pressure Gages.....American Schaeffer & Budenberg Corp.
4 Federal Gauge Co. gages for refrigeration plant.
Richardson-Phenix lubricators on pumps, engines, etc.....S. F. Bowser & Co.
Piping, electrical work, plumbing..John J. Davis & Sons Co.

Electrical Equipment

7 Panel Switchboard installed by The Electrical Mfg. Co. for John J. Davis & Sons Co. Two Sangamo indicating and recording d.c. kw-hr. meters; four Weston Model 57 ammeters; two Weston Model 57 voltmeters; three ITE circuit breakers. Two panels carry house switches; Remote control switches by Sundh Electric Co.
2 Ridgway Dynamo & Engine Co. balancer sets; one set, two 6¼-kw., 115-v., 50-a., 1200-r.p.m. machines; one set, two 3¾-kw., 115-v., 1500-r.p.m. machines.

Three-Wire Distribution System Handled from Well-Equipped Switchboard

Figure 1 shows the switchboard for handling the distribution system throughout the hotel. Two panels carry knife switches for the various circuits. Two other panels carry the integrating and recording wattmeters and the remaining three carry the circuit breakers for the three generating units with their ammeters and generators field rheostats. Voltmeters are mounted on brackets at the right of the board as shown. The balancer sets are shown at the left of Fig. 1. Electrical circuits are carried in conduit from the switchboard. A gage board located in the engine room, as shown in Fig. 5, gives the engine operators full information about steam conditions. This is a marble board, carrying indicating gages for boiler pressure, city water pressure, and vacuum, together with recording gages for boiler pressure and low pressure steam.

Exhaust from the engines is carried by the 12-in. exhaust header laid in a trench in the engine room floor, to the boiler feed water heater. If necessary, a 12-in. riser, as shown discharges steam to the atmosphere through a relief valve. A branch connection on this header, shown on Fig. 5 just to the right of the boiler feed pumps, is furnished to take exhaust steam through an oil separator to the absorption type refrigerating machine, which will be described later.

Identification Colors Used on Piping

As the illustrations show, the various steam and water pipe lines have been fully equipped with suitable drips, traps and separators. A separator is placed immediately ahead of each main engine throttle valve. One feature of the plant that immediately attracts the eye is the system of designating piping by colors. Steam piping is the usual cream color, or white. Cold water pipes are painted green, hot water are pink, brine circuits are black, sewage lines are grey and high pressure ammonia lines are red.

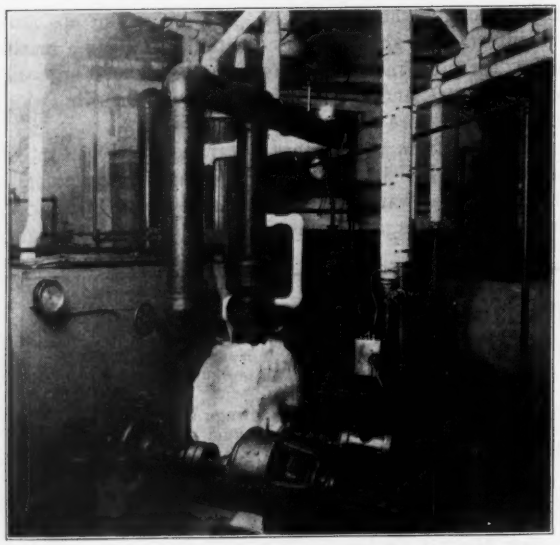


FIG. 6. ABSORPTION TYPE REFRIGERATION PLANT HAS CAPACITY OF 40 T.

For ice making and refrigerating service in the hotel, an absorption type ice machine of 40 t. capacity is located in the refrigeration room. Figure 6 shows some of the parts of this system, the machine covered with frost being the strong liquor pump. Parts of the condenser, generator and ammonia pumps are shown. Brine is pumped by a duplex plunger pump to an ice tank with a capacity of 40 cans of 300 lb. each for ice making. A motor driven centrifugal pump is installed for auxiliary brine-pumping. Brine is also pumped through a drinking water cooler, shown in Fig. 5. When water at 50 to 70 deg. F. is available for ice making, exhaust steam at about 2½ lb. gage can be used in this refrigeration system, but when the water is warmer, the pressure must be 18 to 20 lb., obtained either by running the engines at that back pressure or, if there is heating load on, by adding live steam.

Water for boiler make-up and house service is obtained from the city mains at 7 cents per hundred cubic feet. All this water is treated by a Permutit water softener with a capacity of 68,848 gal. per 24 hr. at 0 hardness, before going to any of the pumps; a 150-g.p.m. booster pump is installed in the softened water line. Hot or cold softened water is pumped through the hotel by two Worthington duplex pumps equipped with Fisher pump governors. Drinking water is taken from a shallow artesian well, sunk through the power plant floor. A 300-g.p.m. duplex plunger pump lifts this water about 8 ft. and pumps it through the water cooler to the house piping.

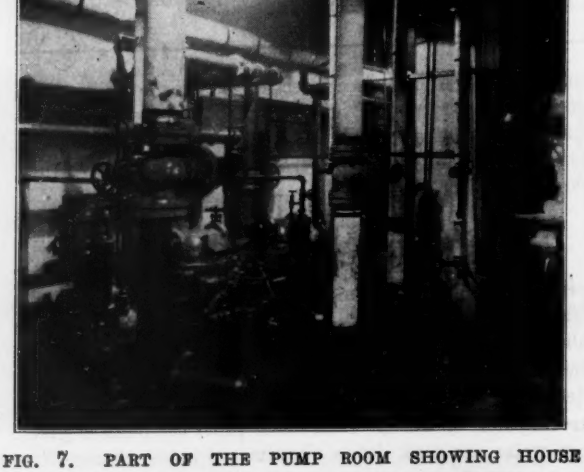


FIG. 7. PART OF THE PUMP ROOM SHOWING HOUSE SERVICE PUMPS AND PART OF WATER SOFTENER

Two Laidlaw air compressors belt driven by 230 v., d.c. motors supply compressed air for cleaning motors, repair work and sewage ejection. Sewage is handled by two 150-g.p.m. sewage ejectors. The heating system of the hotel contains about 60,000 sq. ft. of radiation, the vacuum return system being used. This system is equipped with two Worthington duplex vacuum pumps governed by Boylston pump governors. For vacuum cleaning service in the hotel a vacuum turbine is installed in the pump room.

The chief engineer's office is equipped with the Teletype system for communicating with the main office of the hotel. Remote control switches for balancer sets and other electrical equipment are also placed in the office.

Holabird & Roche, Architects, Chicago, Ill., designed and supervised construction of the Morton Hotel, including the power plant. W. Charles Taggart is managing director of the hotel and Vern E. Kingsland is chief engineer. We are indebted to the above-mentioned for data and photographs used in this article.

Refractory Service Survey of Power Plants

IN A BOILER FURNACE the service which a refractory will give is fixed by the properties of the refractory itself and the conditions to which it is subjected. It is well known that the deterioration in service is greater than that which standard laboratory tests indicate and that the furnace temperature alone does not fix their length of life. Considerable laboratory investigation has been done on refractories, but there has been little coordinated study on the relationship of the refractory, fuel use, and furnace conditions. To attempt to remedy this and to obtain some measure of the relationship, a thorough study has been started by the Bureau of Mines of the Department of Commerce. A preliminary survey was made of a number of representative power plants in widely separated locations and using different fuels, and the data gathered coordinated, and presented in a report to the co-operative committee represented by C. F. Hirshfeld of Detroit. The first intensive study of a particular plant was made at that of the New York Edison Co., at Sherman Creek. Due to other experimental work being conducted there, furnaces using both stokers and powdered coal were available, so that measurements of furnace operations under a variety of conditions were possible. Special furnace setting modifications were put in by the company and continuous records obtained of refractory and furnace temperatures as well as records of the fuel, boiler operation, and flue gas.

The next intensive study will be at the plant of the Commonwealth Edison Co. in Chicago, and will be partly in co-operation with the University of Illinois, which is conducting special investigations for that company.

Electric Power Development in Chicago District

HISTORICAL SKETCH OF THE EARLIER CENTRAL STATIONS; MANY ENGINEERING ACCOMPLISHMENTS HAVE LED THE FIELD; CRAWFORD AVENUE STATION AND OTHER RECENT DEVELOPMENTS; PLANS FOR THE FUTURE. BY WILLIAM S. MONROE*

AS AN introduction to his paper, Mr. Monroe gave a brief historical sketch of electric power generating stations in Chicago, pointing to many engineering practices which were first successfully tried in the Chicago system. He showed how the ever-increasing need for wider distribution, more power and greater economy had led to the abandonment of the early plants and the building of new large generating stations containing in each case the most efficient equipment known to the industry at the time. This all led up to the conditions existing at the time work was started on the Crawford Avenue Station. The remainder of Mr. Monroe's paper was as follows:

In the latter part of 1922 design was started on the Crawford Avenue Station. In building this plant another attempt was made toward a distinct improvement in power station efficiency by taking some more or less radical liberties with the steam cycle. A steam pressure of 550 lb. at the turbine throttle was adopted, nearly twice the highest pressure that had before been used in this country, and considerably higher than had ever been used except in an experimental way. The steam temperature adopted was 725 deg. F., about 50 to 75 deg. higher than previously. Compound turbines were used and the exhaust from the high pressure turbines was taken back to the boiler room and "reheated" in a separate "reheat-boiler" of special design. The turbines were designed for extracting steam from two or three stages for the purpose of heating the feed water, a scheme which had been used to a limited degree before, and which contributes considerably toward improving the cycle efficiency, increases the available capacity of the turbine by taking work off the low pressure wheels and reduces the size of the condensers.

Another departure in this station is the use of vertical condensers standing up through the turbine room floor instead of the usual horizontal ones, set underneath the turbine. This form of condenser was adopted largely on account of the slimy quality of the circulating water from the Drainage Canal, it being the idea that the vertical tubes would keep clean for a longer period than the horizontal, and thus maintain a better average vacuum.

Analysis of the operating cycle of this plant indicated that with the low grade Illinois coal which we are using, and given a good load condition for all the turbines, a plant efficiency of 1½ lb. of coal per kw-hr. should be obtained equivalent to about 15,000 B.t.u. per kw-hr.

Three turbine units were ordered for this station as the first installation, and the No. 1 unit, like the first horizontal turbine at Fisk street, was imported from C. A. Parsons & Co., Ltd., of England. This has a capacity of 50,000 kw. The No. 2 unit was built by the General Electric Co. and is of 60,000 kw., and the No. 3 is a Westinghouse of 50,000 kw. These turbines, as well as the boilers, reheaters (or interstage superheaters) and other features of the plant have been described in the technical press and it is unnecessary to go into them here. A fourth unit is now on order. This is a 75,000 kw. General Electric machine.

*President of Sargent & Lundy, Inc., Chicago, Ill. Abstract of paper presented at the Midwest Power Conference, January 26-29, 1926.

SERVICE RECORD AT CRAWFORD

The General Electric unit, No. 2, was the first to go into service and went on the system November 14, 1924. The Westinghouse unit was started in March, 1925, and the Parsons in May. The General Electric unit, however, did not go into operation with reheating until last May, the Westinghouse in July, and the Parsons has not yet been run with reheat for the reason that several months back it was decided to hold up the reheat boiler for unit No. 1 until some experience was obtained with reheating on the other turbines. This has been advantageous as it has been possible to make some changes in this reheat boiler that will be of value. The plant is, therefore, not yet in full operation and will not be until the latter part of this year.

During the first eight or nine months of the year operation was difficult due to delays in getting the boilers, fans and various other parts of the equipment into service and to some trouble encountered with the tube joints of the economizers. One of the turbines is running now at somewhat reduced capacity and efficiency because of some blade trouble that recently developed.

These experiences, while similar to those likely to be encountered in starting any large new plant, were perhaps aggravated by the unusual character of much of the equipment, and the numerous details that were new and untried and had to be worked into operating condition. But in spite of these conditions, the operating efficiency has been fairly satisfactory.

In the month of October the station had an output of 58,760,000 kw-hr. and an efficiency of 1.54 lb. coal per

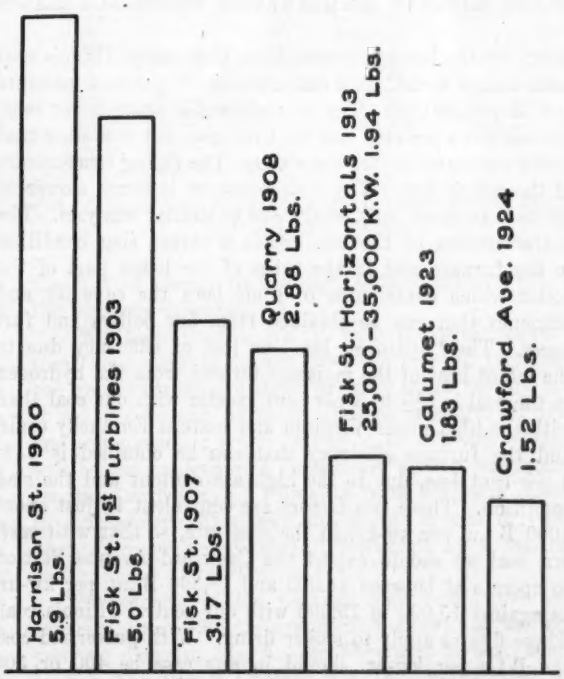


FIG. 1. GRAPHIC COMPARISON OF COAL CONSUMPTION LB. PER KW-HR. OF STATIONS BUILT OVER PERIOD SINCE 1900

kw-hr., equivalent to 15,400 B.t.u. per kw-hr. (the coal averaging 9984 B.t.u. per lb.). Of this output, however, 11,400,000 kw-hr. were from the Parsons unit running without reheat and at less than half load during the day and shut down at night and started up again in the morning. Under this condition of load, the efficiency of the Parsons unit with its boilers was not better than 17,500 B.t.u. per kw-hr., and on that basis the efficiency of the other two units was 14,900 B.t.u. per kw-hr. When the three units are all finished, and with improved load conditions on the station, there is every indication that the efficiency originally estimated of 15,000 B.t.u. per kw-hr. will be obtained.

Results in Coal Economy

In considering these figures, however, it must be borne in mind that the Crawford Avenue Station, like all of the Chicago stations, is handicapped in the matter of fuel efficiency by the low grade coal from the central Illinois coal fields that it burns. This coal contains 15 per cent moisture and 15 per cent ash. The iron content is about 2 per cent, the sulphur 4 per cent and the hydrogen, not including that in the moisture, is over 4 per cent. The fusing temperature of the ash is low. The coal moreover is much slower to ignite than most coals, even those of similar analyses. The characteristics of the ash create a severe slag condition in the furnace and in the tubes of the lower part of the boiler which contributes to limit both the capacity and efficiency that can be obtained from our boilers and furnaces. The "hydrogen loss" or loss of efficiency due to the latent heat of the moisture formed from the hydrogen in the coal is 2½ to 3 per cent greater with our coal than with the high grade Virginia and eastern Kentucky coals, and the furnace efficiency that can be obtained is 3 to 4 per cent less, due to the high ash content and the slag condition. These two factors are equivalent to just about 1000 B.t.u. per kw-hr. in the coal rate, so that with eastern coal we should expect the Crawford Avenue Station to operate at between 14,000 and 14,500 B.t.u. per kw-hr. as against 15,000 to 15,500 with our central Illinois coal. These figures apply to stoker firing. With pulverized coal the B.t.u per kw-hr. should in any case be 400 or 500 B.t.u. lower.

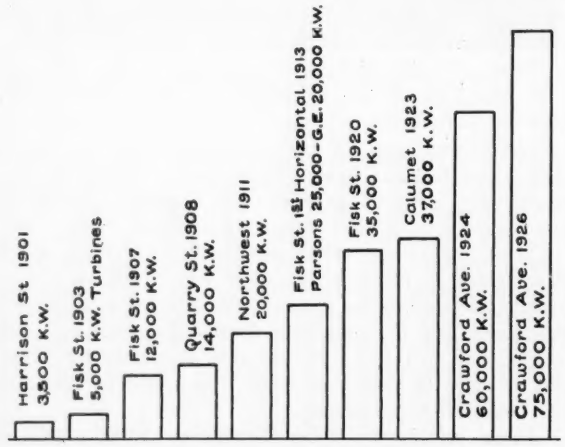


FIG. 2. SIZE OF GENERATING UNITS INSTALLED AT DIFFERENT POINTS IN COMMONWEALTH EDISON CO.'S PLANTS

It should be stated, however, that although the coal used in the Chicago stations is of inferior grade, the ownership of its own mines in a coal field less than 200 mi. from the city has been one of the greatest factors in maintaining low priced electric power in Chicago, and was of the utmost importance in making it possible for the Commonwealth Edison Co. to go through the war period without increasing its rates for electric energy

It is often asked why pulverized coal was not used at Crawford Avenue. All that can be said in answer to that question is that with the high ash and high moisture content of our coal and the low B.t.u. value, any economic balance in favor of pulverized coal worked out to be questionable, and like Shakespeare's most famous hero, we preferred to bear the furnace ills we had, rather than fly to others that we feared might be worse. Besides such considerations, the question of dust and smoke from the stacks of such a large plant near the center of the city was an important factor. The smoke problem with the coal that we burn has been serious, but over a period of years we have solved it fairly well for chain grate operation. But although the smoke at Crawford Avenue is almost negligible, we have had complaints on account of the sulphurous gas from our stacks, and have decided to increase their height by 65 ft.

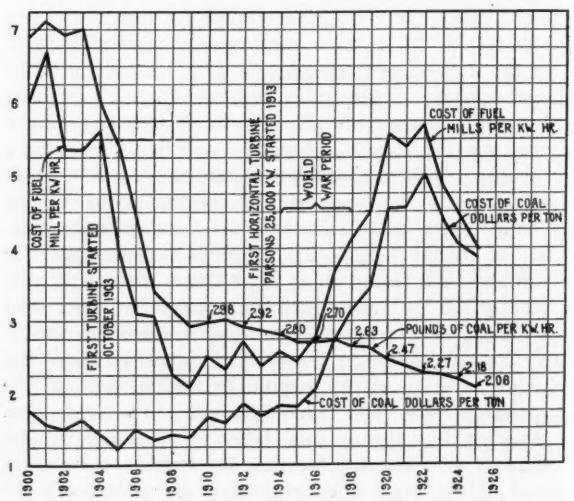


FIG. 3. FUEL ECONOMY OF THE TOTAL SYSTEM OF THE COMMONWEALTH EDISON CO.'S PLANTS

The improvement in station efficiency in the Chicago District since the beginning of this century is shown in the diagram of Fig. 1 and the advancement in the size of the units in Fig. 2, and in Fig. 3 is shown the pounds of coal per kw-hr., the cost of coal per ton and the cost per kw-hr. for each year since 1900. These figures are for the entire Commonwealth Edison system. It is interesting to note from this diagram that from 1910 to 1920 the pounds of coal per kw-hr. were reduced from 2.98 to 2.47, and from 1920 to 1925 from 2.47 to 2.06. During the 5 yr. since 1920 the Commonwealth Edison Co. has converted 13,782,580 t. of coal into electric energy, and had the station efficiency remained through that period, the same as it was in 1920 (2.47 lb. per kw-hr.) the coal consumption would have been 15,428,144 t., so there has been in the last 5 yr. period a conservation of 1,645,564 t. of coal, and a saving of approximately $7,000,000.00 to the stockholders of the company and to its light and power

consumers. The average coal rate for the entire system was 3.0 lb. per kw-hr. in 1910, and the month of October last was the first month in which it went below 2.0 lb. and it is to be hoped will remain there.

It will be noted, however, from the diagram of Fig. 3 that since the beginning of the World War the cost of fuel per unit of output has been far more dependent on the cost of coal than on the fuel efficiency of the power stations and undoubtedly this will continue to be the case.

There are now five major power stations in the city of Chicago and several small ones with a total capacity of 885,500 kw. and they transmit energy to a total of 257 sub-stations, large and small, by underground cables at 9000 and 22,000 v. on the 25 cycle system and at 12,000, 20,000 and 30,000 v. on the 60 cycle system and the power stations are all interconnected by underground "tie-lines" at the same voltages. These tie-lines serve not only to stabilize the power supply throughout the city and to insure its reliability, but are an important factor in the reduction of the average power production costs for the entire system, for they make it possible to run the more efficient units most of the time on what is called the "base load" and to use the least efficient units on the "peak loads."

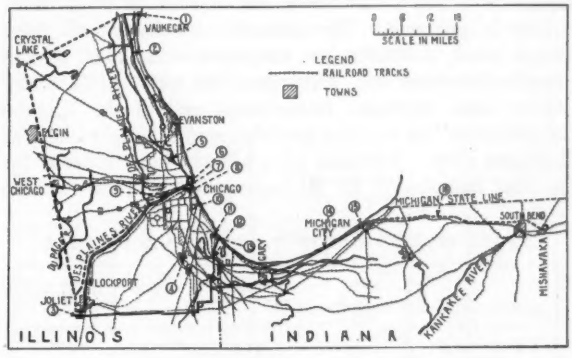
Station Interconnections in Chicago District

This interconnection is now being extended to take in the stations in the districts around Chicago. The map in Fig. 4 shows the location of all the large power stations in the Chicago district. The Commonwealth Edison Co. operates only in the city of Chicago. The territory immediately around the city in Illinois is served by the Public Service Co. of Northern Illinois and that in Indiana by the Northern Indiana Gas & Electric Co. and the Midland Utilities Co.

Besides the power stations in Chicago, there are those of the Public Service Co. at Waukegan on Lake Michigan, about 36 mi. north of the center of the city; Joliet, about 40 mi. southwest of the city; Blue Island, immediately south of the city, and several smaller stations in the territory. There are also the East Chicago station of the Northern Indiana Gas & Electric Co. and the small station of the Midland Utilities Co. at Michigan City. These stations, along with those in the city, supply electric energy to an area of about 5400 sq. mi. and the district has a frontage on Lake Michigan of 92 mi., running from Waukegan on the north to Michigan City on the southeast.

Within two or three years these stations will all be connected together and with the Chicago stations by a system of 130,000 v. tie-lines running all around the city. The first sections of the high tension outer system are already in service as indicated on the map; one line runs from Waukegan to the north limits of the city and from there is being connected to the Northwest station by 130,000 v. underground cables. Another 130,000 v. tower line runs from Joliet to Calumet and extends across northern Indiana to Aetna, about 2 mi. east of Gary, and is now being extended to Michigan City, where a large new station is to be built on the lake front. By the end of the current year, this line will be further extended to connect to the "Twin Branch" station of the American Gas & Electric Co. east of South Bend, Ind. During the coming year, Joliet will be connected to Crawford Avenue and this line soon after will be extended outside the city limits and run north to connect at Crystal Lake with a line running west from Waukegan.

When the new station is built at Michigan City and the high tension interconnecting circuit is completed, it will be possible for a unit at Waukegan Station to serve as a reserve for one at the Michigan City Station which might be out of service for overhauling—not that Waukegan will transmit energy to Michigan City, but it will transmit to the Northwest Station in Chicago, the Northwest to Crawford, Crawford to Calumet, and Calumet to Michigan City. If a unit is out of service at Waukegan,



Public Service Co. of Northern Illinois
Total 25 cycle, 14,500 kw. Total 60 cycle, 172,500 kw.

Principal Generating Stations	Small Stations not Included on Map	
1. Waukegan Station (New) 60 cycle, 60,000 kw.	Waukegan Station (Old) 25 cycle, 25,000 kw. 60 cycle, 7250 kw.	Streator Station 60 cycle, 2065 kw. 3325 v. d.c.
2. 132,000 v. transmission line Waukegan-Evanston	Joliet Station (Old) 60 cycle, 1750 kw.	Kankakee Station 60 cycle, 1240 kw.
3. Joliet Station 60 cycle, 50,000 kw.	Joliet Hydro-Station 60 cycle, 3675 kw.	Wilmington Station 60 cycle, 200 kw.
4. Blue Island Station 25 cycle, 12,000 kw. 60 cycle, 36,500 kw.	Oak Park Station 60 cycle, 2000 kw. 250 v. d.c.	Lacon Station 60 cycle, 200 kw.
	Maywood Station 60 cycle, 3250 kw.	Pontiac Station 60 cycle, 300 kw.
	Evanston Station 60 cycle, 645 kw.	Highwood Station 60 cycle, 2040 kw. 500 v. d.c.
		Wyoming Station 60 cycle, 175 kw.

Commonwealth Edison Co.
Total 25 cycle, 321,000 kw. Total 60 cycle, 522,500 kw.

5. Northwest Station 25 cycle, 85,000 kw. 60 cycle, 80,000 kw.	7. Grove St. Station 60 cycle, 12,500 kw.	10. South Side Elevated (40th St.) 11,700 kw. 650 v. d.c.
6. Fisk St. Station 25 cycle, 160,000 kw. 60 cycle, 50,000 kw.	8. Quarry St. Station 25 cycle, 56,500 kw. 60 cycle, 28,000 kw.	11. Calumet Station 60 cycle, 187,000 kw
	9. Crawford Ave. Station 60 cycle, 164,000 kw.	

12. 132,000 v. transmission line
Joliet-Chicago Heights-Calumet
P.S. Co. of Northern Illinois
13. Site of State Line
Generating Station
14. 132,000 v. transmission line
Lansing-Aetna-Michigan City
15. Site of Michigan City
Generating Station
16. 132,000 v. transmission line
under construction

FIG. 4. MAP SHOWING PRINCIPAL GENERATING STATIONS IN CHICAGO DISTRICT

the flow of energy in the high tension circuit will be in the opposite direction.

This high tension circuit with the great power stations connected to it will give the city of Chicago and the great industrial district growing up so rapidly around it in Illinois and northern Indiana a source of reliable and cheap electric power second to none in the world, and will be the nucleus of a superpower system which already reaches (with varying voltages) from northern Wisconsin to southeastern Kentucky and within a year or two will have Chicago connected to Pittsburgh by a continuous tower line at 130,000 v.

The growth of the Chicago load and power station capacity since 1900 is graphically shown in the accompanying diagram Fig. 5. On December 23 last, the peak load in the city of Chicago was 780,500 kw, that of the Public Service Co. was 113,600 kw., and of the northern

Indiana district 38,500 kw., making a total for the entire Chicago district of 932,600 kw. By next year the combined load will have passed 1,000,000 kw. and it is likely to reach 1,500,000 kw. by 1930, and 2,000,000 by 1934.

The installed capacity at the end of 1925 was 885,000 kw. in Chicago, and in the Public Service Co. and Northern Indiana about 205,000 kw., making a total of 1,090,000 kw. available for the entire Chicago district. The capacity by 1930 will probably be in the neighborhood of 1,650,000. The accompanying table shows the power station capacity at the present time, what it will probably be in 1930, and also the ultimate capacity that may eventually be developed on the power station sites on which work is now in progress. The ultimate capacity on all these sites is nearly 4,000,000 kw. and there is included, besides Crawford Avenue and Waukegan, the new "State Line" site on Lake Michigan immediately east of the Illinois-Indiana state line and the new station on the lake shore at Michigan City. Turbines have already been ordered for the first installation at Michigan City, and this station

POWER STATION CAPACITY OF CHICAGO DISTRICT

	Capacity		
	1926	1930	Ultimate
COMMONWEALTH EDISON CO.			
Fisk St.	230,000	282,000(rebuilt)	350,000(rebuilt)
Quarry St.	84,000	84,000	84,000
Northwest	165,000	205,000(rebuilt)	208,000(rebuilt)
Calumet	187,500	210,000	210,000
Crawford Ave.	235,000	410,000	750,000
Small Stations	59,000	7,500	
Total Comm. Ed. Co.	960,500	1,198,500	1,539,000
PUBLIC SERVICE CO. OF N. ILL.			
Waukegan	60,000	160,000	500,000
Joliet	50,000	50,000	150,000
Blue Island	48,500	48,500	48,500
Small Stations	16,040	16,040	
Total P S Co.	174,540	274,540	698,500
NORTHERN IND. REGION			
East Chicago	28,000	28,000	
Michigan City		60,000	600,000
State Line		200,000	1,000,000
Small Stations	1,125	19,825	
Total N Ind.	29,125	307,825	1,600,000
Total Capacity of District	1,164,165	1,780,865	3,837,500

will be developed ultimately to a capacity of about 600,000 kw.

The power station at State Line will be built on land which is now being filled in out in Lake Michigan. It is planned to develop at State Line a station of 1,000,000 kw. capacity, and the first unit will probably be a compound unit with three turbines and generators having a combined capacity of 200,000 kw. The plans contemplate five such units on the site. This station will have many new features and, so far as the ultimate cost of power is concerned, in all probability, will be as much of an advance on Crawford Avenue as Crawford Avenue is in comparison to Calumet.

Besides these sites, the Commonwealth Edison Co. owns a tract of land on the Drainage Canal about 4 mi. down stream from the Crawford Avenue station and on this site can be developed another station about as large as Crawford Avenue which will ultimately be 750,000 kw. The Public Service Co. owns a power station site on the Des Plaines River on the opposite side of the river from the present Joliet station, and on that location can be developed another station of 1,000,000 kw. capacity.

So it is safe to say that on the sites in and around Chicago, now owned by the associated companies, there will ultimately be developed a total capacity of nearly 6,000,000 kw. The load in the Chicago district is likely to require that capacity sometime between 1945 and 1950, but long before that time power will be transmitted into Chicago from the central Illinois coal fields. The generation of electric power at the coal mines has been advocated for years in connection with superpower development, but it is not the location of the coal that has determined our power station sites, but the location of the power demand and the necessity of a large supply of water for the condensers. It must be remembered that in any modern power station we pump through the condensers not less than 400 t. of water for every ton of coal burned—this to absorb the waste heat which cannot be converted into energy by the steam cycle.

There are few localities in this country where coal mines are adjacent to a plentiful supply of water and in Illinois, on account of the geologic formation, no coal operator would sink a shaft within several miles of the Illinois River. But the associated power companies of the Chicago district already own a large tract of land on the

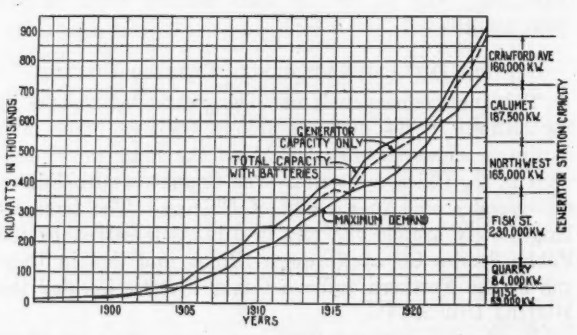


FIG. 5. GROWTH OF MAXIMUM LOAD AND GENERATING CAPACITY OF THE COMMONWEALTH EDISON CO.'S SYSTEM SINCE 1895

Illinois River within about 150 mi. of the city, which, within a few years, will be developed to supply electric energy to the Chicago district over a 130,000 v. transmission line.

Such an enterprise has not been warranted in the past because the cost of shipping coal into Chicago has been less than the cost of transmitting electric energy and it could not be justified at the present time except that it be done in large units and at a high load factor. The Illinois River site is in contact with a railroad which runs through the great central Illinois coal fields and taps the mines that are now owned by the Commonwealth Edison Co. and which railroad is also controlled by the associated companies, so that this Illinois River plant will be assured of the cheapest possible cost of coal. On this same site, moreover, will probably be developed eventually, a great coal storage and coal handling plant, from which coal will be shipped by water to the Chicago stations after the Illinois waterway is completed.

These far-reaching plans for power development for the Chicago District are only to insure a reliable supply of cheap electric power which will keep pace with the greatest possible industrial development that will come about in this region. By these improvements will be maintained what the late Dr. Steinmetz called a "pool of power"

that will be second to none in the world and will make Chicago the power center of this country

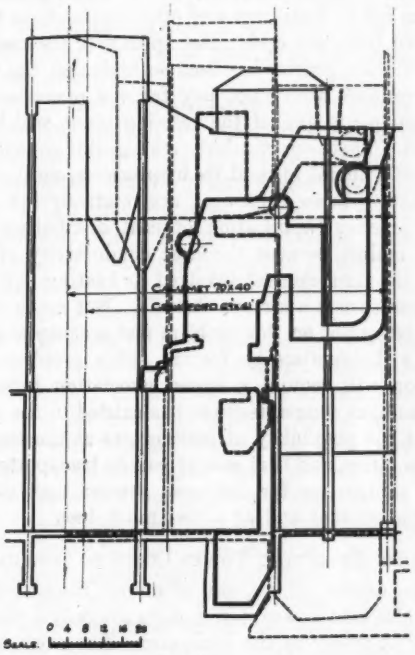
Looking to the Future

It may be asked if, in the future development of this great "pool of power" there are any possibilities for further reduction in the cost of energy. It may be said that so far as present day power station efficiencies are concerned, we are getting so close to the ultimate possibilities of the steam cycle that further improvements will come only with great difficulty and at prohibitory capital expenditures. Undoubtedly it is impossible to go on reducing the coal rates indefinitely and reckoned in B.t.u. per kw-hr. there is a figure somewhere, beyond which it is impossible further to improve the plant efficiency with any form of the steam cycle. Just what that base line is cannot be stated with absolute assurance of accuracy. Professors A. L. Mellanby and Wm. Kerr in a paper read before one of the English Engineering Societies in February, last, analyzed the steam cycle and predicted that 1250 lb. per sq. in. would be the ultimate limit of steam pressure, and they estimated that at this pressure and with 90 per cent boiler plant efficiency a theoretical fuel consumption of 9400 B.t.u. per kw-hr. generated may be reached, but their cycle contemplates an initial steam temperature of 900 deg. F (which is quite impractical with any metals we have today) and also requires reheating the steam twice, first at 500 lb. and again at 180 lb. and nothing is said of the cost. But granting the correctness of these figures and granting the practicability of the system, when we allow for auxiliary power (and the percentage of auxiliary power goes up very fast with increase in pressure) and allow also for the difference between average operating and the theoretical efficiency this would indicate a possible average monthly plant efficiency in the neighborhood of some 11,500 B.t.u. per kw-hr. output.

S. Z. deFerranti of Manchester, England, one of the most expert engineers in the matter of practical thermodynamics now living, told the writer, some months ago, that in his opinion there can be no gain in going to a steam pressure of over 850 lb. per sq. in. The theoretical gain that can be achieved above this pressure is so small that the cost of getting it is more than likely to far outweigh the percentage of improvement that can be accomplished. Until we can get metals at reasonable cost which can stand temperatures much higher than we are now using, probably the real limit of practical steam plant efficiency is somewhere between 12,000 and 13,000 B.t.u. in the fuel per kw-hr. of output and something less than 14,000 is now in sight with a high grade coal.

There are, however, other methods of electric power generation that may be developed within a few years, and the combustion mercury vapor and steam cycle of W. L. R. Emmet indicates the possibility of a station efficiency 20 or 25 per cent better than can be achieved by any form of steam cycle.

While the steam cycle is doubtless approaching its limits of efficiency, there are still some possibilities of improvement, but there is more opportunity so far as the immediate future is concerned, in the reduction of capital costs. The Crawford Avenue Station cost less per unit of capacity than Calumet, but while the fixed charges on the two stations are about the same, the production costs at Crawford Avenue have been so reduced that the fixed charges on the capital are just about as much as the total cost of operation, so that the reduction of fixed charges is as important as reducing operating charges. Reduction of power station costs means getting more capacity out of the equipment, that is, getting more capacity out of the turbines, generators, boilers and furnaces, as well as buildings. New developments in turbines as well as in boiler and furnace construction, particularly for pulverized coal, indicate that a material reduction can be made in the coming years in the cost of power stations. Some indication of the improvement that has been made in recent years in the Chicago stations in the matter of boiler capacity and building requirements for them is indicated in Fig. 6. This diagram shows that the boiler of Crawford unit No. 4 takes up less building space and requires a much lighter structure than the Calumet boiler, and the former has an



	Average K.W. Capacity	Area of Bldg. Space Sq. Ft.	Area of Bldg. Space Sq. Ft. per K.W.	Volume of Bldg. Space Cu. Ft.	Volume of Bldg. Space Cu. Ft. per K.W.
Calumet Boiler	10000	2800	.28	277200	27.7
Crawford-Unit-#4	15000	2829	.188	260268	17.3

FIG. 6. COMPARISON OF BUILDING SPACE OCCUPIED BY BOILERS AT CALUMET AND CRAWFORD UNIT NO. 4

average capacity of 15,000 kw. as against an average of only 10,000 kw. for the Calumet boiler.

Improvements in Coal Consumption

There are also other possibilities which tend toward the reduction of power costs in the Chicago district. During the past year the electric power companies in the Chicago district burned over 3,500,000 t. of coal. By 1930 this figure will have increased to over 5,500,000 t. The handling of this tonnage of coal through the freight terminals of the Chicago district and in the yards of the power stations is in itself an engineering problem of important magnitude, and our present methods are susceptible to much improvement.

Better methods in the handling and storage of coal, and the handling of coal traffic with a view to getting more

continuous operation of the mines and improving the train schedules for the railroads may reduce the ultimate cost of coal at the power plant site by a considerable percentage, and it must be borne in mind that 10 or 20 per cent reduction in the cost of coal is just as good (except for the conservation of coal) as the same percentage improvement in plant efficiency. And, as pointed out before, the cost of coal is likely in the future to have far more effect on the cost of electric energy than power station efficiencies.

There is another field of industrial activity, which, in the near future, will probably have an important bearing on the production of electric energy and that is the preliminary or "partial" distillation of coal before burning the residue coke in the electric power station. We all know that there are great quantities of gas, gasoline, oils of various kinds, fertilizers and other by-products that can be distilled from any coal. But up to date the cost of any coal distillation process has been so high that the value of the by-products would not pay for the operation of the distillation plant and of the refining plant which has to go with it. This is particularly true in this country where the cost of mineral oil and its by-products, most of which are similar to those from coal, are relatively low.

The practical application of coal distillation is very difficult, mainly because the heat conductivity of coal is low and the time element involved in heating it to distilling temperature is a serious obstacle. But much scientific effort is being put on this problem and a cheap and simple method will doubtless be found. This problem of coal distillation will require a closer association between the electric and gas companies than has existed in the past. It holds out the possibility of making gas at the coal mines for use in cities, and heat energy can be transported as gas through a pipe line for distances greater than electricity can be transmitted and at a cost much less.

Factors Affecting Power Costs to Consumers

In the matter of the cost of power, it must be borne in mind also that power station costs are only a part of the total cost of power to the consumer. The average selling price for electric energy to the consumers of the Commonwealth Edison Co. was 2.19 cents per kw-hr. in 1925. The average production cost at the power station was only about one-fourth of that figure and including fixed charges on the power station was somewhat less than one-half. The rest is in the expense of transmission, substations and distribution, meters, connecting customers and general expenses. There is opportunity for reduction in the transmission and distribution costs, and probably in all the other items.

Even when it comes to the cost of converting electric energy into light (and the lighting load is still about one-third of the total) I cannot but quote J. L. Haldane, the eminent professor of physics at Cambridge University, who in his brilliant essay on the possibilities of scientific achievement, written under the classical title of "Daedalus," ventures the statement that "to light a lamp as a source of light is about as wasteful of energy as to burn down one's house to roast one's pork." He further goes on to prophesy that "in fifty years light will cost about a fiftieth of its present price and there will be no more night in our cities."

At no period in the history of mankind—at no time, even since the beginning of the last century which ushered in the great scientific and industrial awakening, have the possibilities of scientific achievement and of industrial improvement been more marked than on this opening of the second quarter of the twentieth century.

The generation and distribution of electric energy has been the chief agency by which the great inventions of the age have been made of practical use to the people. We have thus far only opened the door to the possibilities of their service to mankind. The greatest need is to extend this service that it may reach out and touch the daily life of each and every individual in his home and at his work. It puts a magic power to the tool in his hand, makes the workman a master of a machine and not a slave to his toil. It abolishes drudgery, brings light and freedom for thought and inspiration into his life.

Engine Room Signals

TRANSMISSION of instructions from load despatcher to the operators of prime movers, switch gear and boiler plant or between the various operators is a vital part of station operation and such transmission must be quick, accurate and unmistakable, if mishaps are to be avoided. To a certain extent, automatic operation can be utilized to good advantage but individual operation is essential and may be preferable for larger and more complicated plants where it is desirable to watch the action of equipment as it is brought into or out of service.

Telephone communication has the disadvantage that it may be misunderstood, also requires the operator to be at a fixed point. Visible signals overcome these objections but do not provide for other than a limited number of routine orders.

In a combination of the two systems would seem to be found the ideal method. A visible system, with audible alarm which calls the operator's attention to the indicator will take care of routine operation, permit of handling equipment at a distance from the signal and cannot be misunderstood. A reply back signal insures that the despatcher's instructions have been received, understood and carried out. The auxiliary telephone system provides for extraordinary operation and for preliminary instructions or forewarnings of load changes; also for keeping the despatcher informed as to condition and availability of equipment.

Diversity of systems is now available so that any conditions may be met for operation of individual units, an aggregation of units or any desired combination, can be driven from direct or alternating current lines and arranged for any desired sequence of operating instructions. These, combined with a telephone system which has a call indication on the visible signal dial, would seem to give the ideal method for control of station operation.

The Independent Power Co., Pomeroy, Ohio, has been formed under state laws with a capital of $1,000,000, to operate electric light and power properties in this section, as well as in West Virginia and parts of Southern Ohio. The company is said to be negotiating for the purchase of a number of going properties in this vicinity, to be taken over and consolidated. In addition, it is purposed to arrange for new line construction for physical connection of the various properties, as well as substations for commercial service, and other facilities. The new company is headed by Scott C. Ridgway and associates.

Machine Control and Regulation of Combustion

Control Systems Must Be Accurate and Continuous in Operation and Must Govern Various Elements Simultaneously and With Sufficient Power. By J. F. Shadgen*

IN MODERN POWER plants, the most important problem undoubtedly is the spending of the fuel dollars. According to the national statistics of the N.E.L.A., the coal item makes up over 75 per cent of the net production cost per kw-hr. It is possible, theoretically, to transfer about 80—82 per cent of the B.t.u. contained in coal into steam in the boilers without economizers. The losses are represented by some 4 per cent on account of hydrogen, 1.15 per cent on account of ash, some 10—11 per cent up to the stack on account of sensible heat, 2—3 per cent radiation, unaccounted for and variations (safety factor). Tests show that these results can be obtained. Experienced crews have secured boiler efficiencies around 79—80 per cent for periods of several weeks in certain plants. The practical monthly operating figures of even the best run plants show that hand operation efficiencies above 75 per cent are the exception, while 72—73 per cent indicate credible operating results. The average is lower, of course, being, according to statistics, about 70 per cent.

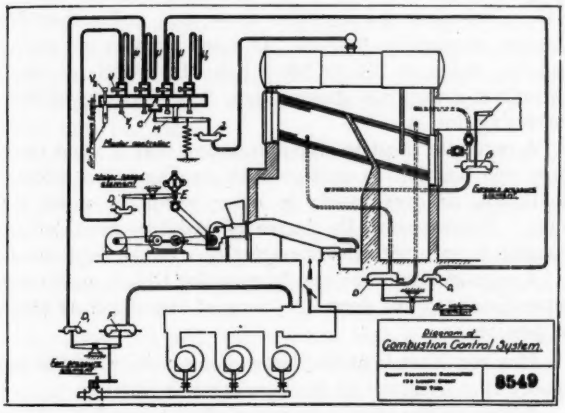


FIG. 1. SCHEMATIC DIAGRAM OF A MECHANICAL COMBUSTION CONTROL SYSTEM

Reasons given for these discrepancies are usually the variable load conditions and the low load factor meaning banked boilers and coal quality. The real reason is incomplete boiler house equipment and reliance on the human element to supply the missing apparatus. Firemen are used as regulators and controllers; they are supposed to judge speeds, pressures, volumes and drafts. They do their best but the results prove that this is not sufficient. In spite of all kinds of instruments, some indicating, some recording, that are put at their disposal, the insufficiency of the human element is apparent, as it is inherently wrong to ask emotional and complex living beings to act as regulators.

These fundamental conditions have been clearly recognized and, during the last five years, machine control and machine regulation have been developed. Complete mechanical combustion control systems have been applied to individual boilers and complete plants. These systems aim to supersede the man by machines in matters of regulation, and to elevate the fireman to an efficient maintenance operator and supervisor—duties which no machines can ever perform.

Results with some of these systems are so gratifying that they have become firmly established. The consistently remarkable monthly efficiencies in plants equipped with machine control set new standards for boiler room operation, independent of load factor and load variations. Monthly data of several large boiler houses, built over twelve years ago with a multiplicity of small boiler units, prove that 76—77 per cent can be considered a normal achievement. In modern plants, monthly efficiencies (overall stoker, furnace, superheater and boiler) of 78—80 per cent will be average. The load in these plants varies considerably from industrial to railroad and city lighting, the load factor from 30—65 per cent and all possible emergency conditions have been met by suitable equipment.

To achieve the desired result—that is, maximum efficiency always with all loads and all variations of load—it is essential that the control system avoid the two basic

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FIG. 2. THESE MASTER CONTROLLERS GOVERN BOILER OPERATION AT HUDSON AVE. STATION

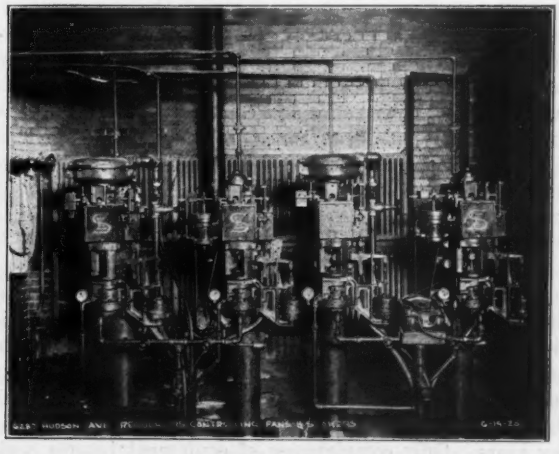

FIG. 3. REGULATORS CONTROLLING FORCED DRAFT FANS AND STOKER SPEEDS AT HUDSON AVE. STATION

shortcomings of the human operator. Men are inaccurate and do not work continuously; men guess as to whether settings are correct and, having manifold duties, they change the various settings off and on, the hit and miss of their judgment being emphasized by the intermittent corrections. Machine control, therefore, must above all

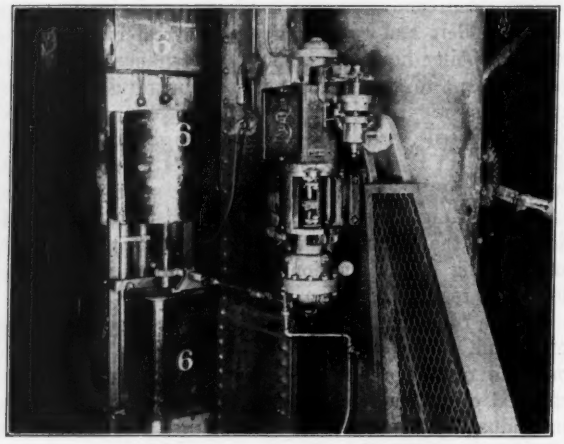

FIG. 4. THIS STOKER SPEED REGULATOR OPERATES A DRUM CONTROLLER THROUGH RACK AND PINION

be accurate, then continuous in operation and, last, must simultaneously regulate all factors that influence the result.

Accuracy is the basic specification because it furnishes the foundation for the desired result. To control any function accurately, it is necessary to measure its value and to maintain it at a certain definite value. In a combustion control system, fan pressures will have to be measured and controlled accurately, air volumes will have to be measured and controlled and the same applies to the speed of the coal supply and the draft conditions. Accuracy demands clear-cut separation of each element from the others, as well as each application. A regulator can perform only one duty well; it can never satisfy two commands without becoming erratic and inaccurate, that is, without losing the very reason of its installation.

Continuity of operation demands sturdy machines requiring little attention, designed along practical lines and according to the highest standards of the governor art.

The multiplicity of functions influencing the combustion reaction and its efficiency under boilers makes it necessary to co-ordinate all elements simultaneously in order to maintain the proper ratios and correct proportions all the time and to isolate disturbances of one function to that field so as to avoid interfering counter-effects or unbalance.

Each Element Should Be Governed by an Accurate, Individual Regulator

It follows, then, that an adequate mechanical combustion control system has all elements governed by individual regulators of great accuracy, whose operations are properly co-ordinated by a central master apparatus. That is the logical conclusion, which has been proved by the results achieved in practical applications during the last few years. Only completeness of equipment insures positiveness of results; all half-way solutions or compromise installations have given only partial results. The developments of the last years have clearly brought out that point. The interference of human guesswork must be entirely eliminated in the execution of the governing operations. Many early attempts at machine regulation failed on this score and it is vital to diagnose correctly the real reason of these failures if progress is to be continued.

Of course, no analysis of the specifications a control system has to meet is of any value if it does not include definite data concerning the regulators themselves. A regulator must be sensitive; that is, it must start to react on a small variation of the value of the element under control. For instance, if pressure is controlled and the range is 0 to 6 in. of water, the regulator must respond to small fluctuations such as 0.1 in. of water. If over fire pressure is controlled and the range is 0.05 in. to 0.15 in. of water the regulator must start and correct for changes as small as 0.01 in. If speed is to be controlled and the range is 125 to 500 r.p.m., the regulator must not admit a variation greater than 2 or 3 r.p.m. without correcting for it.

A regulator must be stable, meaning that it must move from one position to another with precision and without oscillation or over-travel; in other words, it must not hunt. Furthermore, its degree of stability must be adjustable to cope with the characteristics of the application.

A regulator must be speedy, meaning that it must move immediately to cut down the time of transition as much as possible.

If a regulator is at the same time sensitive, stable and speedy, the accuracy of its regulation is obvious.

Added to the above characteristics, a regulator must have sufficient power to execute the orders received and to move the valves, dampers, rheostats and controllers so as to change flow, speeds, pressures and tensions to suit the demands of regulation.

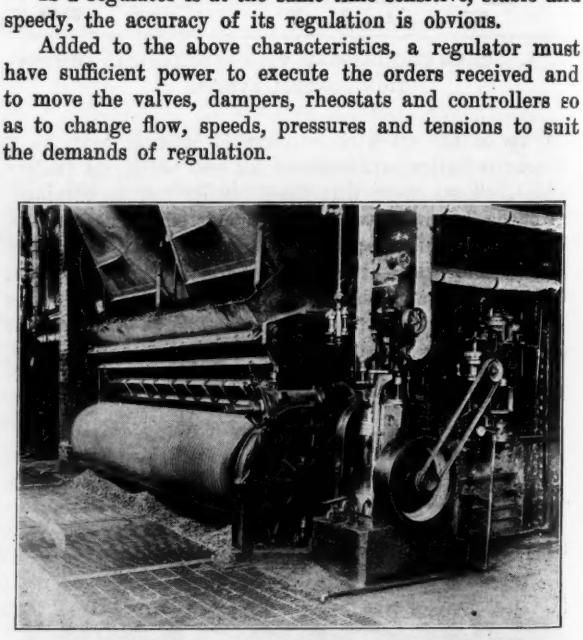

FIG. 5. REGULATOR APPLIED TO STOKER WITH ENGINE DRIVE

If built as outlined above a combustion control system will unload an impossible task from the firemen and give them real help in running their plants. It will become an additional tool just like any other governor. The operators will supervise and will have the feeling that their orders are executed at each vital point immediately and without error. That the efficiencies will be high is a matter of course, the inevitable result of correct engineering.

Furnace Design for Traveling Grate Stokers---I

PRESENT APPLICATION OF ARCHES IS DUE TO FORCED DRAFT, INCREASING DEMANDS FOR HIGHER RATINGS AND THE USE OF SPECIAL FUEL SIZES. BY H. S. COLBY*

NATURAL DRAFT chain grate stokers were designed at first principally for the burning of low-grade bituminous coal. The furnace designs of the earlier installations provided for an arch over the front of the stoker of a length of approximately two-thirds to three-quarters of the length of the stoker grate surface. The function of this arch was to ignite the fuel by reflecting heat from the central and incandescent section of the fuel bed back on to the fresh fuel passing in under the stoker grate. Combustion was progressive, the process being a gradual ignition of the fuel bed from the top surface down until the entire bed of coal was ignited to the grate surface, a gradual burning out of the combustible and the formation of an ash residue containing more or less carbon which eventually passed over the rear end of the stoker into the ashpit.

Natural draft provided practically a uniform flow of air in the furnace at all points above the fuel bed. The fuel bed, however, did not offer a uniform resistance to the flow of air. The coal, as admitted into the furnace, was closely packed, contained more or less moisture and offered the maximum resistance to air flow through the fuel bed. After this coal had passed into the furnace and the moisture and hydrocarbons had been distilled off, the fuel bed resistance was less and finally, as it approached the rear of the furnace and the fixed carbon content had been burned out, the ash residue offered but little resistance to the passage of the air. This difference in fuel bed resistance resulted in the gases from the front end of the stoker being lean in oxygen and the gases from the rear of the stoker containing a surplus of oxygen. The gases rising from the central section were more representative of the proper proportioning of combustible gases and air.

Efforts were made to improve the operation of natural draft stokers by the installation of fuel retarders, water-backs, dump plates and other mechanical means having as their object the compression or building up of the thickness of the ash residue on the rear end of the stoker so as to create a more uniform fuel bed resistance and reduce air infiltration through this section of the fuel bed. To some extent conditions were improved by the adopting of water-backs, particularly as these devices not only created some additional resistance through the rear end of the fuel bed but quite effectively sealed the air leakage into the furnace from the ashpit.

FIRST ARCHES WERE SET LOW

At first arches were set quite low in an attempt to carry the gas from under the arch with a high velocity in the horizontal plane so that those gases deficient in oxygen might be carried into the stream of gas rising from the rear of the stoker where there was an excess of oxygen. These streams of gases mixed to some extent but the average setting did not provide sufficient length of gas travel after the gases from both ends of the stoker came together, to insure diffusion and completion of combustion before the gases reached the heating surface of the boiler. Appreciation of this fact led to the adoption of the practice followed in some of the larger public service stations in the Middle West of setting the stokers under the low end of the boiler, covering the lower rows of tubes with "C" tile and providing a long gas travel before reaching the heating surface.

Power plants increased in size and boilers were operated at higher ratings, creating a demand for increased fuel burning capacity. This led to the consideration and application of forced draft to the chain grate stoker. Furnace designs of the early forced draft stoker installations followed closely the design developed in natural draft operation. Operation of forced draft stokers soon developed the fact that this furnace design was unsuited for forced draft practice.

Dividing of the grate area into zones or sections approximating the three distinct stages of combustion, permitted the distribution of air to meet the requirements of each stage of combustion. Higher pressures were carried in the zones over which the distillation of the hydrocarbons and moisture were taking place with the result that more air was introduced through this section of the fuel bed for the burning of the gases liberated at this point. Light pressures were carried in the zone under the rear end or that section over which the ash residue was passing so that the infiltration of air so common in natural draft practice was eliminated. Air in a proper amount for supporting the combustion of the fixed carbon was admitted through the central zone or section of the fuel bed.

Such operation resulted in an appreciable increase in the quality of gas, the elimination to a considerable extent of the hydrocarbon loss, and a pronounced increase in the capacity or the amount of coal that could be burned on a given grate area. Trouble was experienced with the arches due to the erosive effect of the high static pressures used on the first and second, particularly the second zone of combustion, and to the higher temperatures resulting from the burning of the coal with less excess air and at higher combustion rates.

ZONING SYSTEM CHANGES ARCH DESIGN

It was immediately recognized that with the zoning system it was not necessary to use arches either as long or set as low as had been customary in natural draft practice. This was due to the fact that it was no longer necessary to attempt to mix the streams of gas from the extreme front and rear ends of the stoker. Accordingly, arches were set considerably higher and shortened, experimentation determining the height and length best suited to give satisfactory ignition for a coal of given analysis.

Adopting forced draft materially increased the capacity and flexibility of operation and resulted in an improvement of the quality of gas but had not in the least improved the quality of ash. With this furnace design only the rear end of the fuel bed was exposed to the boiler heating surface and the propagation of heat by radiation from the fuel bed to the boiler heating surface took place partially from the highly incandescent central section of the fuel bed, but principally from the rear section which represented the ash residue. As a result, the ash residue

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chilled so quickly that when air was applied through the last zone in an attempt to burn out the combustible, there was not sufficient heat in this ash residue to furnish the specific heat of combustion to this air, as it percolated slowly through the fuel bed, and instead of burning out, the combustible passed over the end of the stoker into the ashpit and the air admitted diluted the furnace gases.

This problem was solved by the introduction of the double arch furnace design, in which an arch was installed over the rear end of the stoker covering practically the third zone or that zone on which the ash residue was being burned out. By shielding this zone from the boiler heating surface and preventing the radiation of heat to the boiler tubes and in addition thereto reflecting heat from the highly incandescent central section of the fuel bed on to this ash residue, the temperature was maintained above the ignition point. Air supplied to this zone resulted in the burning of the combustible and producing a satisfactory quality of ash.

Introduction of the rear arch necessitated the shortening of the front arch but this did not influence the

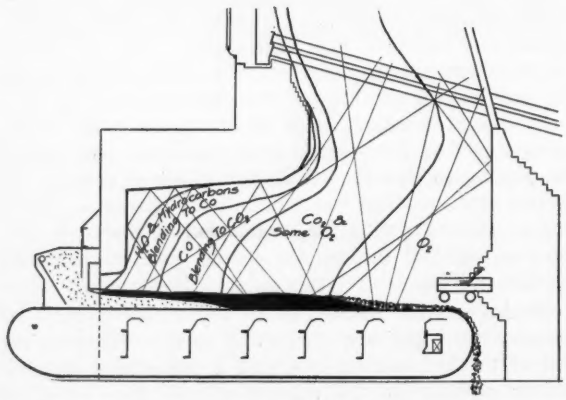


FIG. 1. THIS IS THE TYPE OF FURNACE DESIGN FIRST USED WITH NATURAL DRAFT CHAIN GRATE STOKERS. FORCED DRAFT REVEALED THE LIMITATIONS OF THE WATER-BACK

ignition of the fuel, as the location of the rear arch was such as to advance the position of the bridge wall to a point where both the latter and the rear arch assisted in reflecting heat on to the fuel admitted under the gate and, if anything, further increased the rapidity of ignition. Shortening the front arch and the installation of a rear arch placed the opening between the arches directly over the zone where the extremely high rate of combustion was taking place and where the highest static pressures were used. This section of the fuel bed was formerly located under the extreme rear end of the front arch and the high static pressure caused an erosion of the front arch at this point, even after it was set as high as ignition would permit. Placing the space between arches over the zone of high temperature and high pressure eliminated arch erosion and greatly increased its life.

Difficulties experienced with sprung arches resulted in the development of the suspended arch, the composite structure of steel and fire tile so universally used today.

During the period in which these modifications were taking place in the design of furnaces for burning bituminous and other high volatile coals, changes were being made in the design of furnaces for the burning of anthracite coal. With the development of the forced blast, traveling grate stoker for the burning of anthracite and other low volatile fuels a furnace design had been developed which closely approximated that of the single arch furnace for the burning of bituminous coal. This furnace was quite satisfactory when burning No. 2 buckwheat anthracite or the steam size coal that had formerly been burned on hand-fired grates. The sizing of this fuel was such that the resistance to the passage of air through the fuel bed did not necessitate extremely high static pressures and the fuel could be burned out gradually in a manner similar to the burning of bituminous coal.

In the preparation of the larger sizes of anthracite, both domestic and steam, there was accumulated over a period of many years, a large tonnage of coal sizing smaller than No. 2 buckwheat. Coincident with the development of the traveling grate stoker efforts were being made to burn this small coal. The forced draft, traveling grate stoker proved quite successful in burning a size slightly smaller than No. 2 buckwheat—a coal known as No. 3 buckwheat which screened all through a $\frac{3}{16}$-in. and approximately 25 per cent through a $\frac{3}{32}$-in. round mesh screen.

Due to the finer sizing it was necessary to use considerably higher static pressures when burning the No. 3 buckwheat coal and it developed that there was a distinct limit to the combustion rate in the burning of this coal. If the fuel bed was increased in thickness beyond a given point, the static pressures had to be increased to an extent that would cause the fuel bed to drift and the very fine coal would be carried up and burned in suspension in the furnace and in fact carried over into the boiler and breeching. Thin fuel beds offering less resistance burned more uniformly but there was a limit to the grate speed obtainable, established by the rapidity of ignition. Finer coals than No. 3 buckwheat could not be burned on the single arch furnace due to the drifting of the fuel bed and the sky-rocketing of the fine particles.

It was not until the double arch furnace was applied to the burning of anthracite coal that sizes smaller than No. 3 buckwheat were burned successfully. The double arch furnace permitted the distribution of air in such a manner that the highest static pressures could be carried under the rear arch where the fine coal, blown off the fuel bed was deflected forward horizontally by the rear arch and dropped back on the front end of the fuel bed. Low static pressures carried on the section of the fuel bed under the front arch and under the throat resulted in the gases arising from this section being deficient in oxygen but the amount necessary for combustion was delivered through the fuel bed under the rear arch at the point where the high static pressure was applied. Rich gas from the front of the furnace and the oxygen from under the rear arch were intimately mixed as they passed through the throat over the zone of highest incandescence which provided temperatures sufficient to complete combustion of the gases within a short distance.

Intensity of the combustion in the rear zones under the rear arch insured the burning out of the combustible in the ash residue. For this reason the adoption of double arches, after the original design of rear arch had been lengthened, permitted the burning of fine anthracite coals at satisfactory efficiencies and capacities. This will be discussed in a later issue.

Natural draft chain grate stokers were used for burning low grade sub-bituminous and lignite coals. The customary furnace design was a single long, front arch and a high bridge wall with a somewhat restricted area between the end of the arch and the face of the bridge wall, through which the gases passed from the furnace. Considerable difficulty was experienced in burning these fuels except at a low combustion rate due to the high moisture content, ranging between 15 and 35 per cent, which chilled the front end of the furnace and retarded combustion. Distillation of this moisture resulted in the entire front end of the furnace just back of the stoker gate being filled with steam or vapor. This vapor as it passed up and back under the arch gradually became superheated and transparent, permitting the arches to function to some extent in the usual manner. Combustion could not start, however, until the fuel had passed back into the furnace much farther than was necessary with moderate moisture fuels and the maximum obtainable combustion rates were thereby limited.

Chain Grate Stokers Enter the Lignite Field

When forced draft chain grate stokers were first introduced in this field, the furnace design as usual followed the natural draft practice. It soon developed that with the zoning system of air control the distillation of the moisture content could be materially hastened by practically eliminating all air from the first compartment of the stoker. This permitted a shortening of the front arch and, with less excess air used for combustion, higher temperatures were developed, thus materially increasing the combustion rates obtainable. Rear arches were used to lower the combustible in the ash.

In Fig. 1 is shown an outline of a furnace design which, up to 2 or 3 yr. ago, was considered quite suitable for the burning of bituminous coal. The outline of the double arch furnace shown in Fig. 2 is representative of the present trend of furnace design for the burning of this fuel. These designs are typical for the horizontal water tube boiler, vertically baffled, set in the vicinity of 12 to 14 ft. from the floor to the bottom of the front header. Although these designs are both subject to modification with height of setting and size of boiler unit, they are sufficiently representative to be used in illustrating the reasoning responsible for the present trend of furnace design.

Diagrams Show Stages of Combustion

Light lines shown in Figs. 1 and 2, drawn from the central or incandescent section of the fuel bed to the arches and from the arches back on to the fuel bed, represent the heat propagated by radiation from the fuel bed to the arches and thence to the coal passing in under the stoker gate. These light lines are also drawn from the fuel bed to the boiler heating surface and represent the heat propagated by radiation from this bed of fuel to the boiler heating surface.

In Fig. 2 a number of lines are drawn from the central section of the fuel bed to the rear arch and from the rear arch back on to the ash residue. These lines indicate the reflection of heat from the central section of the fuel bed on to the ash residue at the rear of the stoker. A study of these lines, together with the relative exposures of the fuel bed to the boiler heating surface, will indicate that with the single arch furnace the rays of heat passing to the boiler heating surface are reflected partially from the highly incandescent section of the fuel bed but principally from the rear end of the fuel bed. This results in chilling the rear end of the fuel bed below the ignition temperature and thus producing a high ashpit loss.

With the double arch furnace design (Fig. 2), the rear end of the fuel bed is shielded from direct radiation to the boiler heating surface and in addition thereto the rear arch is designed to reflect a considerable amount of heat from the central and incandescent section of the fuel bed back on to the ash residue. This maintains a temperature in this ash residue sufficiently above the ignition point of the combustible so that a small amount of air applied to this section will result in the burning out of most of the combustible.

In the double arch furnace a much larger section of the grate area is exposed to the boiler tubes, even though the distance between the front and rear arches is much less than the distance from the end of the front arch to

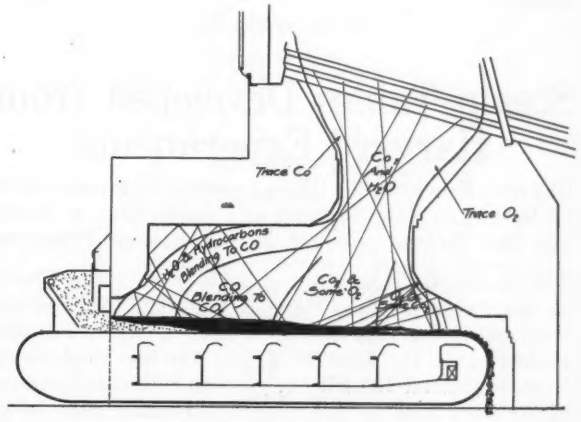


FIG. 2. BY REPLACING THE WATER-BACK WITH A SUSPENDED REAR ARCH, EXCESS AIR AT THIS POINT IS DEFLECTED INTO THE ZONE OF COMBUSTION

the face of the bridge wall in the single arch furnace design. The section of the fuel bed exposed is also that of highest temperature. This increases the propagation of heat by radiation to the boiler and gives the boiler and stoker unit a high per cent of efficiency.

Above the fuel bed (Figs. 1 and 2) are a number of somewhat heavier lines indicating streams of gas of various composition. It is difficult to express in a diagram what takes place in the furnace. Although in actual practice the streams of gas are not stratified to the degree indicated on the drawing, nevertheless stratification exists below the throat substantially as shown.

With both single and double arch furnace, the moisture and low temperature hydrocarbons are liberated immediately after the fuel passes into the furnace under the stoker gate. As the temperature of the fuel bed rises, distillation continues and for a considerable period practically all of the gas liberated from the full bed is form of hydrocarbons and moisture. After the volatile gases have been distilled off the continued heating of the fuel bed generates carbon dioxide and carbon monoxide which subsequently burns to carbon dioxide. On a section of the fuel bed, varying in length depending upon the characteristics of the fuel and load, and immediately following that section on which the distillation of hydrocarbons takes place is a section in which carbon monoxide

is generated. It is impossible to deliver sufficient air through this section of the fuel bed to burn the carbon monoxide to dioxide without retarding ignition. It is not until the fuel bed becomes ignited down through to the grate surface that the highest static pressures can be applied and sufficient air introduced through the fuel bed to burn the gas generated on that section of the fuel bed to carbon dioxide.

Highest pressure is applied to that section of the fuel bed in which the combustible is in sufficient quantity to warrant continuing this high pressure without reducing the temperature of the fuel bed. As the combustible is burned out, the pressure must be reduced with the result that the highest static pressures are carried at points from one-half to three-fourths of the distance from the front of the stoker and then taper off so that the volume of air delivered to the rear zone is just sufficient to support the combustion of the carbon in the ash residue covering this section.

(To be continued.)

Steam Tables Developed from Harvard Experiments

GENERAL ELECTRIC CO., USING THROTTLING EXPERIMENTS OF DAVIS AND KLEINSCHMIDT AS A BASIS, AIDS IN WORKING OUT CHARTS AND TABLES FOR HIGHER PRESSURES

IN A REPORT on the Development of Steam Charts and Tables from the Harvard Throttling Experiments, reprinted in the February, 1926, issue of Mechanical Engineering, J. H. Keenan of the Turbine Engineering Dept. of General Electric Co. gives an interesting account of the work done by that company to obtain some information on steam at high pressures, using as a basis the data presented by Dr. H. N. Davis and Dr. R. V. Kleinschmidt at the December, 1923, meeting of the A.S.M.E. Mr. Keenan's report was presented to the A.S.M.E. Committee on Steam Research and the Extension of Steam Tables, October 20, 1925.

In order to begin work on this subject, it was first necessary to develop into a steam chart some of the throttling experiment data and this required a formulation of the data in such a way that the Joule-Thomson coefficient for any temperature and pressure could readily be found. Such a formulation was devised by Dr. Davis for all pressures under 50 atmospheres throughout the superheated steam region. This formulation was plotted on a chart, not reproduced here, and formed one of the most important parts of the development, because it served directly as a basis for determining total heat and indirectly for calculation of entropy and specific volume. It was then necessary to find the basis from which the complete set of specific heats was to be found, or the hypothetical specific heat at zero pressure. The determinations used were principally those of Knoblauch, including the recent work up to 420 lb. When these data had been plotted, the specific heats for the entire superheated range were determined.

For the region of higher superheats, a formulation of the product of the Joule-Thomson coefficient and the specific heat was developed by Dr. Davis, which fitted closely the values which had been tabulated. Equations developed from the first and second laws of thermodynamics and involving the Joule-Thomson coefficient were used to determine the properties of steam superheats greater than 200 deg. F.

For lower superheats, however, it was necessary to find a different method. The constant total heat line chart could be used to find the total heat at any pressure and temperature if the total heats at zero pressure were known. These were found by an integration involving the specific heat at zero pressure. When this had been done, the total heat along each of the constant total heat lines was known and intermediate values could be determined by interpolation.

Knowing the total heats and entropies above 200 deg. F. superheat and the total heats down to saturation, the additional values of entropy were found by dividing successive small finite total heat increments along the constant pressure lines by the average absolute temperatures in the respective intervals. Having done this there was at hand all the information necessary to the drafting of a Mollier diagram.

Much labor was saved in obtaining data for this diagram by following out a suggestion made by Professor G. A. Goodenough. Charts of differences between the new data and the Goodenough values were drawn up and the entire diagram plotted from these. The smallness of the quantities involved in the different charts greatly reduced the number of calculations necessary to cover the entire superheated steam region.

The report discusses the way in which these calculations were compared and checked with other tables and includes a complete tabulation of specific volumes of saturated and superheated steam between 1 lb. per sq. in. absolute pressure and 1200 per sq. in. absolute. The diagrams mentioned above are also shown.

It is not to be supposed that the new chart and tables are presented as the final word on the properties of steam in the region they cover. The rapid increase in the pressures used in steam-turbine practice made evident the urgent need for more reliable data on steam and prompted this development of the Harvard data. Further information yielded by the A.S.M.E. Steam Research Program will be eagerly awaited. In the meantime these new charts and tables will be of service as a development of the most extensive and dependable empirical data that have yet been published on steam at high pressures.

THE FLORIDA POWER & LIGHT CO., Miami, Fla., will take over and consolidate a group of nine electric utilities operating in this vicinity, and plans for extensions and improvements in generating facilities, transmission lines, substations and other operating properties. The companies comprising the merger include the Miami Electric Light & Power Co., Miami Beach Electric Co., Miami Gas Co., Southern Utilities Co., Daytona Public Service Co., Ormond Supply Co., Lakeland Gas Co., St. Johns Electric Co., and the Southern Holding Co. Service will be furnished at Miami, Miami Beach, Palm Beach, West Palm Beach, Ormond, St. Augustine and other places, with a gross population of more than 360,000 persons. The company will be controlled by the American Power & Light Co., New York, an interest of the Electric Bond & Share Co. The aggregate valuation of the properties is placed at $80,000,000. To provide for the merger and proposed expansion, a bond issue of $30,000,000, is being sold. S. R. Inch is president of the consolidated organization.

British and European Semi-Diesel Engines

RECENT IMPROVEMENTS IN DESIGN HAVE MADE THE HOT BULB OR HOT POINT TYPE POPULAR. BY F. JOHNSTONE-TAYLOR

DESPITE the marked popularity of the cold-starting, airless injection engine with British engineers and power users, the semi-Diesel engine is making considerable headway. There is a tendency on the part of designers to improve the working of these engines, which up till recently were regarded mostly in the light of cheap general purpose units for small power consumption. It is fully realized here that the full Diesel engine with its air blast injection has little advantage to show over the cold-starting engine for loads up to 300 hp., while the latter is a simpler engine and costs less to build. Especially is this the case with some new designs operating with relatively low compression. The semi-Diesel engine appeals to a wide circle of power users, both on account of its low first cost and extreme simplicity. Those

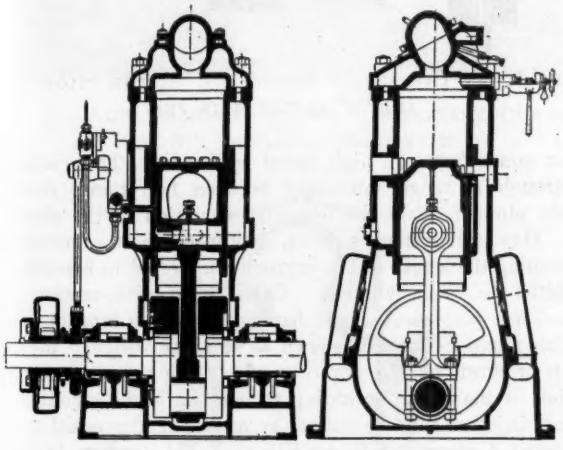


FIG. 1. SECTION OF TYPICAL BRITISH VERTICAL SEMI-DIESEL ENGINE USING HOT BULB IGNITION

designs, however, which may be regarded as orthodox, that is, simple low compression two cycle engines with crankcase induction, show up none too well in regard to fuel consumption and the amount of lubricating oil necessary. Their main field lies in low-priced general purpose power units developing about 60 hp. and in situations where, operation being intermittent, fuel and oil economy is secondary to low first cost.

ORTHODOX PRACTICE OUTLINED

It is not necessary here to discuss at any length what has been referred to as the orthodox type of engine as built by several concerns both in Britain and Europe. They are vertical engines, for the most part designed similar to the engine shown in Fig. 1. Built on the unit principle, with the usual crankcase compression, they vary in size from about 20 to 300 hp. although the last-named size is exceptional. As may be seen the design is light, simple and compact and is also representative of engines built for the propulsion of small craft. On the left is seen the usual crankshaft governor operating on the variable throw eccentric which in turn operates a variable stroke fuel pump. This is the type of governing mainly employed, although as will be shown, the eccentric system is not universal.

SUPPLEMENTARY INJECTION

Naturally, with several well-known builders in the field, each design presents some special feature. As an example, the light load gear of the Vickers engine has as its object the maintenance of proper ignition during any lengthy period of light load running. In this arrangement, as shown in Fig. 2, *a* is the oil pump body, *b* its plunger, *c* the rocker arm driven by eccentric rod *d*, and *e* is the pump priming handle. By means of the little lever *f*, when it is moved to the "light" position, the auxiliary rocker arm *g* is moved into a position in which it de-

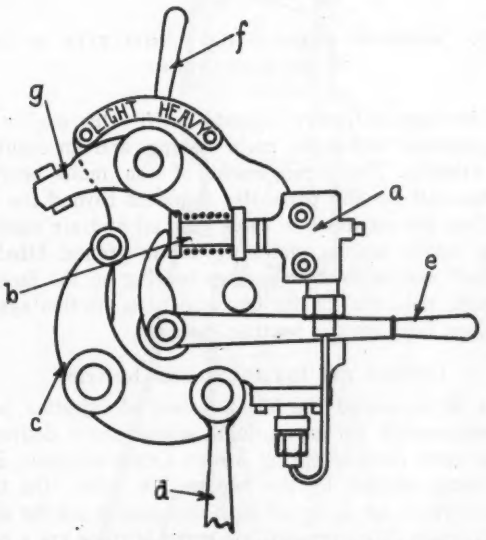


FIG. 2. ON THE VICKERS ENGINE THIS LOAD GEAR MAINTAINS SUPPLEMENTARY INJECTION DURING PROTRACTED PERIODS OF LIGHT LOAD

presses lever *e* a small amount at each stroke 180 deg. in advance of the normal timing. This gives a supplementary injection of fuel sufficient to maintain the heat in the hot bulb at light loads for any indefinite period.

COLD STARTING AND AUTOMATIC CYLINDER LUBRICATION ARE DESIRABLE

Since cold starting has always been desirable, both the Beardmore and the Swedish-Bolinders engine make use of electric starting ignition plugs which, after the engine is warmed up, are switched off and drawn away from the hot bulb. The Vickers engine makes use of what is termed the "cartridge" starter which is an ignitible plug lit and inserted into the hot bulb where it generates intense heat during the starting period. Another feature of this engine is the system of automatic cylinder lubrication which takes the form of a pump operated by the air pressure in the crankcase. This, with piston and plunger properly proportioned, delivers oil at four points around the piston belt at 60 lb. pressure, the oil being supplied to the pump through a sight feed.

Many attendants with a view to economy in lubricating oil really starve the crank chamber and the use of

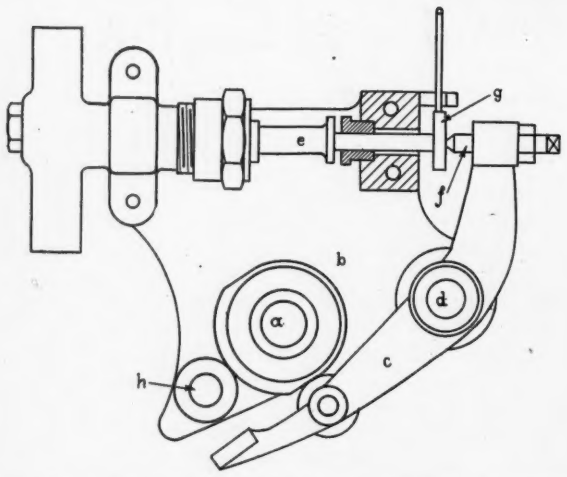


FIG. 3. GARDINER ENGINES HAVE THIS TYPE OF FUEL PUMP MECHANISM

roller bearings naturally suggests itself. One engine has been produced with roller main bearings and for crankpin and wristpin. The arrangement of the main bearings does not call for any particular comment beyond the fact that they are mounted in cases kept oil and air tight by spring loaded sealing plates which are ground fitted on the shaft and, with their springs bearing on the faces of the crank webs run tightly but with little friction against machined faces on the bearing cases.

Devices for Injection and Ignition

As before stated the usual system of injection is by an eccentrically driven, variable stroke pump delivering to the usual form of spring loaded airless atomizer, ignition being effected by the regular hot bulb. On these engines which are equipped with compressed air for starting, lamps with compressed air spray burners are a great improvement on the simple blow lamp in that they effect rapid starting, especially where a hot plug takes the place of the hot bulb. On account of the relatively long fuel lines of this eccentric driven system it does not give exact timing when the fuel pumps are grouped as with multi-cyclinder engines intended for central station work. For this reason some designs operate the pumps from a side shaft. This of course enables the pumps to be placed close to the combustion head and the arrangement calls

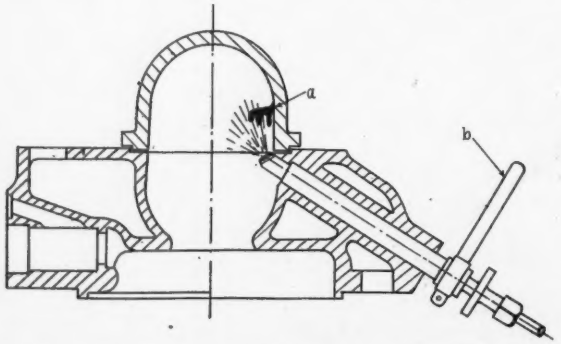


FIG. 4. THIS ILLUSTRATES THE CONSTRUCTION OF THE CYLINDER HEAD ON A GARDINER ENGINE WHICH IS PROVIDED WITH AN INJECTION GRID OR HOT POINT AND AN ADJUSTABLE SPRAY NOZZLE

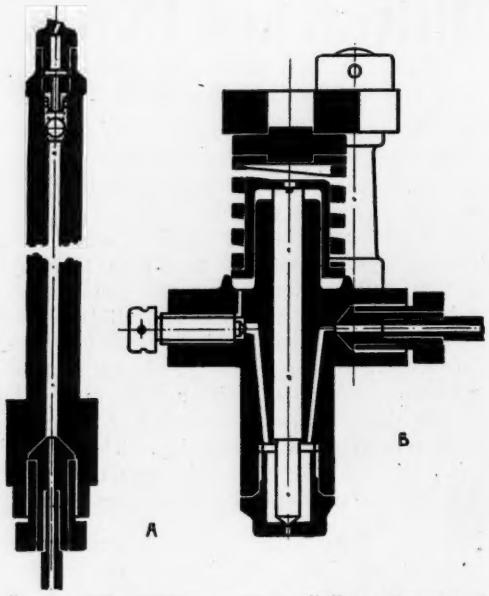


FIG. 5. IN THE PLENTY ENGINE, "A" IS THE PILOT JET AND "B" IS THE MAIN JET

for some form of high speed governor. This, acting through a wedge interposed between fuel pump rocker and plunger, gives the necessary variation to the stroke.

One such system is shown in Fig. 3, where camshaft *a* running the length of the engine is supported in brackets *b* bolted to each cylinder. Cams on *a* give motion to rocker *c* pivoted at *d* and having adjustable tappets at *f*. The pump plunger is shown at *e*. The wedge *g* moved up or down by the governor effects the necessary variation in the stroke according to load while the amount of fuel injected may be varied by adjusting the position of tappet *f* according to conditions. This system is that used on the Gardiner engine, in connection with which may be mentioned the arrangement of the hot bulb and atomizer shown in Fig. 4, where the little injection grid *a* should be noted. This is virtually a hot point and by means of handle *b* the nozzle can be turned by the attend-

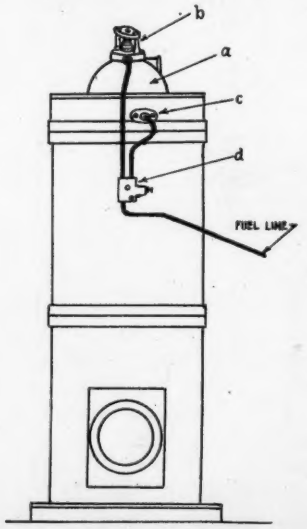


FIG. 6. DIAGRAM OF THE FUEL SYSTEM OF A PLENTY ENGINE

ant so as to direct the spray upon *a* at starting and for light load running or to any other suitable point in the hot bulb according to operating conditions.

The Plenty engine is another design which aims at high efficiency and suitability for central station work and is equipped with side shaft and variable stroke fuel pumps on each cylinder although of rather different design from the aforementioned. The injection system is of some interest in view of the fact that two jets are employed, one for starting and one for running, and the hot bulb is really eliminated, its place being taken by water-cooled combustion head. This has an ignition plug heated externally for starting and against it the spray from the pilot jet A shown in Fig. 5 is directed, this jet being set at a suitable angle in the cylinder head. With the engine warmed up, however, the pilot jet is cut out and the main jet B is put into action. In Fig. 6 is shown a diagram of the fuel system of the same engine where *a* is the water-cooled cylinder dome or combustion head,

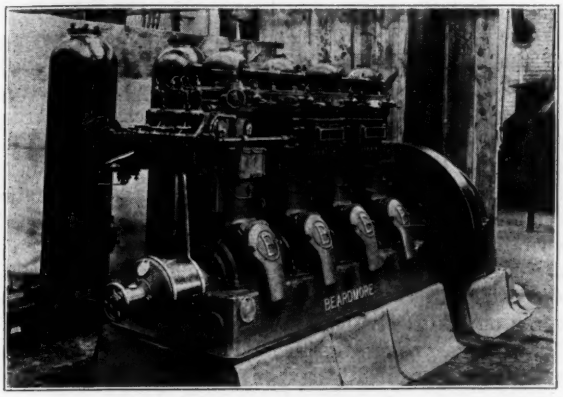


FIG. 7. THIS BEARDMORE ENGINE IS REPRESENTATIVE OF THE HOT BULB SEMI-DIESEL TYPE

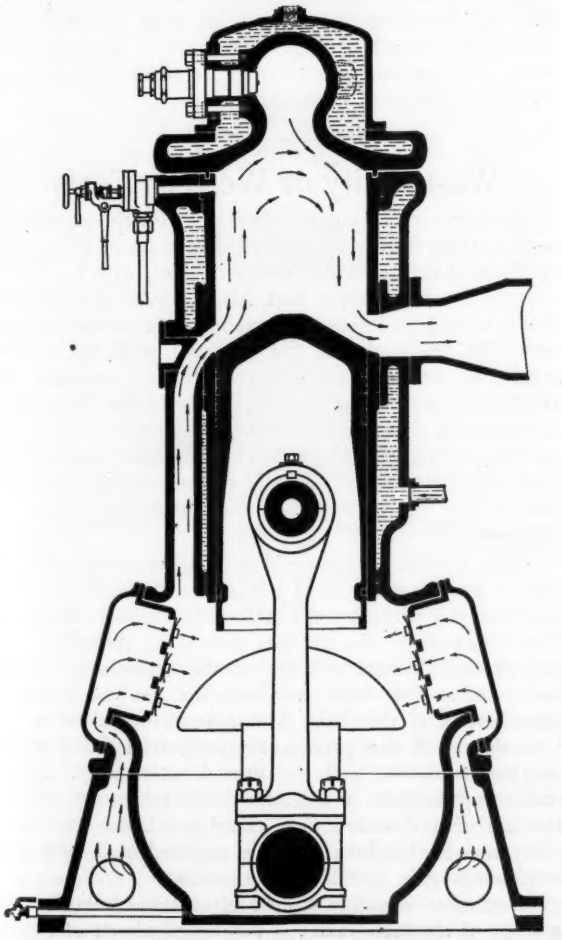


FIG. 8. NEWLY-DESIGNED VICKERS ENGINE WITH WATER-COOLED COMBUSTION HEAD

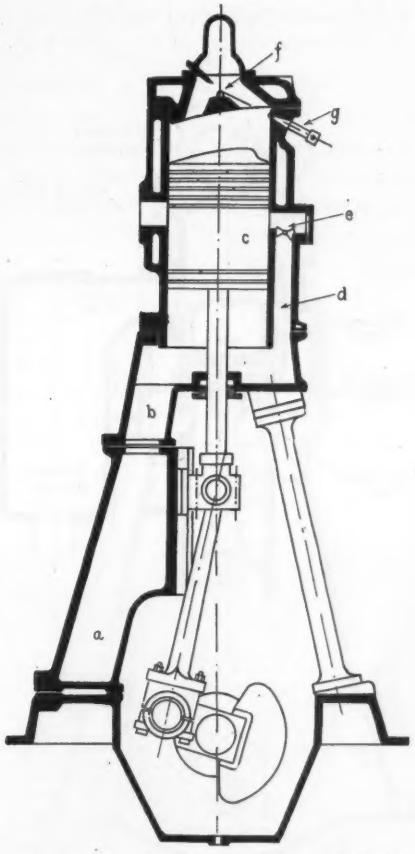


FIG. 9. THIS BOLNES ENGINE, MADE IN HOLLAND, IS OF THE OPEN TYPE

b the main jet, *c* the pilot jet, *d* the isolating valve or change-over valve, while the lamp-heated hot plug is behind the main jet. The latter directs the spray almost vertically, a practice now followed in several large semi-Diesel engines.

Large Types of Engines with High Compression and Superchargers

At present engines of this class exceeding 300 hp. are intended mainly for marine propulsion but they indicate the trend of future development. Mention may be made of the latest Beardmore engine shown in Fig. 7, in which a special feature of interest is a spherical water-cooled cylinder head with the atomizer placed centrally and giving a vertical spray. Working with the high compression pressure of 300 lb. no external heat is required for starting, this being effected by an electric starting plug

fitted in the side of the cylinder head. It should be noted that the piston has an aluminum head and is not water or oil cooled.

At present the Beardmore engine is being developed as a marine unit but Vickers have recently introduced an engine on similar lines, that is, with a water-cooled combustion head and the jet placed at the side. In Fig. 8 is shown the general arrangement of the crankcase, ports, dome and the conical-shaped piston head.

This engine has quite a low compression and represents a type now regarded with considerable favor in Britain, eliminating as it does the disadvantages of the hot bulb. As regards fuel consumption and regular running, it compares favorably with the cold-starting engine without the high compression of the latter type.

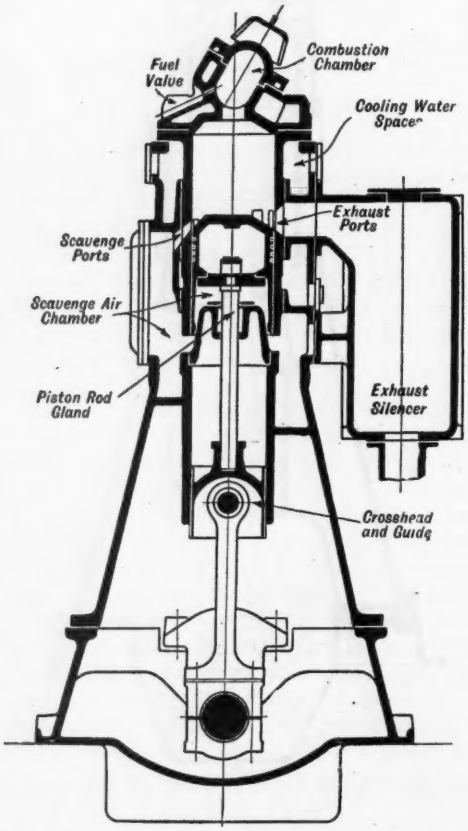


FIG. 10. HERE IS ANOTHER OPEN TYPE ENGINE MADE BY THE MIRLEES CO., IN ENGLAND

Supercharging is a feature of the White engine which, although retaining crankcase scavenging, has an independent air pump. This delivers air through rotary control valves, immediately after the scavenging air has done its work, so that the system is something similar to that of the Sulzer two-stroke Diesel. The same effect is brought about by the Polar engine made by the Stockholm-Atlas Co. This engine has a differential piston which draws a considerably increased volume of air into the crankcase. It works with high compression but there is no hot bulb, the spray being ejected through a single hole spray plate. The cylinder head is domed and the piston head dished, the two forming an elliptical combustion chamber.

Eliminating Crankcase Compression by Using Open Type Engines

Crankcase compression is undoubtedly one of the limiting factors in the development of high efficiency semi-Diesel engines. Its sole virtue is cheapness of construction. On the other hand, where the underside of the piston is used as the air pump the construction of the engine with its essential crosshead naturally is more expensive but the system has been consistently adhered to by the Bolnes Co. in Holland and now is being adopted by the British Mirlees Co. It may be stated that semi-Diesel engines have been highly developed in Holland by reason of the vast numbers used for canal and river craft propulsion. Figure 9 shows a Bolnes engine of the open type, built on steam engine lines. Air is induced through the hollow column *a* into chamber *b* where, after compression it passes into the cylinder *c*. The little hand-operated throttle *d* is for the purpose of throttling the air at light loads. The combustion head is of peculiar shape and is so arranged that the nozzle *e* directs the spray on a little knife edge *f* which is claimed to break up the spray before it reaches the hot bulb. While the cylinder is lubricated by a system common to such engines the rest of the motion is oiled entirely by drips, the consumption of which usually is not more than 1/60 of the fuel oil used.

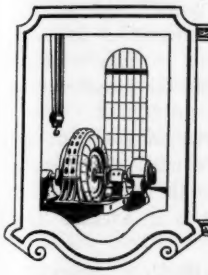
In the semi-Diesel field, the Mirlees engine, shown in Fig. 10, is a newcomer. It differs from the Bolnes in that it is of relatively high speed and is arranged with forced lubrication. Also it may be noted that the hot bulb is of the usual type.

Washability of Western Coals

Work is being continued at the Seattle experiment station of the Bureau of Mines, Department of Commerce, on the washability of fine coal on tables, with particular reference to Washington and Alaska coals. The purpose of this work is to obtain fundamental data on coal tabling, using the float-and-sink test of zonal products, supplemented by screen-sizing tests and chemical analyses. All experiments will be on commercial-size tables. With these fundamental data in hand, it is proposed to attack the problem of cleaning fine sizes of Washington coals which have baffled all attempts to produce economically a washed coal of low ash content even though shown possible by float-and-sink tests.

That portion of the problem relating to the effect of specific gravity and size of particle on the distribution of coal and impurities on the table is practically completed. The information obtained has proved an important step toward the ultimate solution of the problem of tabling bony coals. This work indicated the need of hydraulic classification of the feed. A single-cell coal classifier has been developed and given a thorough trial under widely varying conditions and has proved satisfactory. Appreciable improvement in the work of the table resulted from the use of a classified feed. During all the table tests, every variable has been carefully recorded, and some work has been done in correlating these data.

Particular attention will be given this coming year to a study of the table variables mentioned above, and to the perfection of a multiple-cell coal classifier along lines of the single-cell apparatus developed during the past year.



ELECTRICAL MACHINERY FOR LIGHT AND POWER

Transmission and Distribution Lines---III*

DESCRIPTION OF INSULATORS AND TOWERS AND POLES USED IN MODERN TRANSMISSION LINES. BY STEPHEN Q. HAYES†

IN THE development of high voltage transmission lines, one of the most difficult problems has been the one of securing suitable insulators. On low voltage systems, the requirements for insulation are not severe; the insulators need not be large and therefore the material of which they are made are not subjected to undue mechanical stress. The electrical stress is also of negligible importance and no great demands on material are made in this respect.

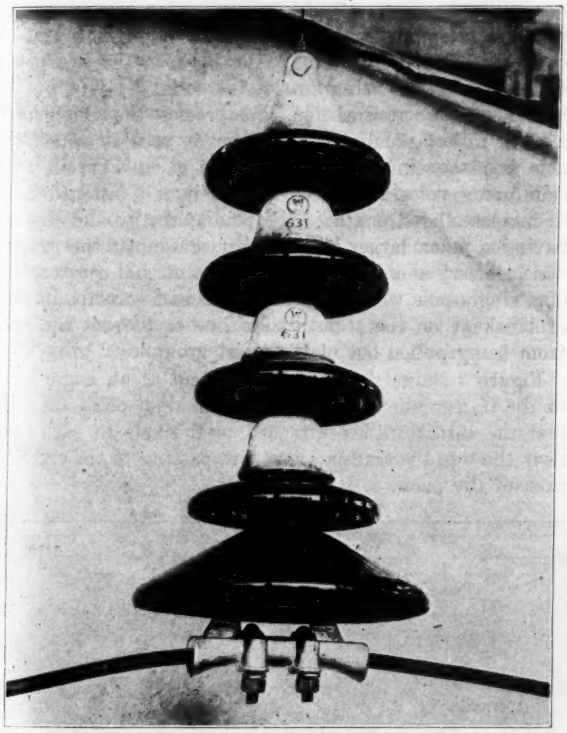


FIG. 1. CORONA SHIELD USED ON THE SEATTLE LINE

For high voltage work, however, the demands are severe, both as regards the ability to withstand electrical stress and mechanical stress, and in recent years insulator design and construction has made notable progress. For voltages above 66,000 the standard 10-in. suspension insulator is used almost universally. Practice varies with respect to the number of insulators installed for a given line voltage. The climatic conditions, the type of line construction, the continuity of service required all have to be considered. The following list is a conservative one affording a high factor of safety under average conditions:

Line Voltage	Number of Units Suspension	Recommended Strain
33,000 v.	2	3
44,000 v.	3	4
66,000 v.	5	6
88,000 v.	6	7
110,000 v.	8	9
132,000 v.	9	10
154,000 v.	10	11
220,000 v.	14	15

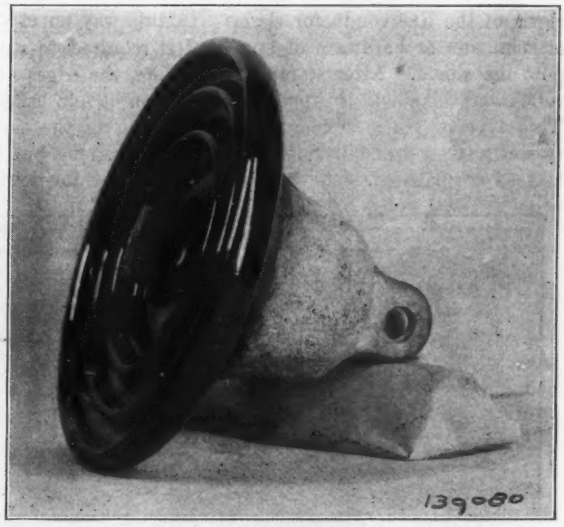


FIG. 2. HIGH STRENGTH INSULATOR, SEATTLE LINE

For very high voltages the voltage distribution along a string of suspension insulators is much distorted so that with all insulators in the string of the same type and size the voltage across the unit next the line conductor is much higher than the voltage across the unit next the grounded steel support. Various schemes have been used to improve this voltage distribution, most of them being based on increasing the electrostatic capacity of the first few sections next the line by the use of metal discs, larger units, guard rings and similar devices.

*The preceding articles of this series appeared in the issues of Dec. 15, 1925, and Feb. 1, 1926.

†General Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

FIG. 3. ANGLE BEND, 165-KV. LINE. CITY OF SEATTLE

In connection with the 165-kv. transmission of the Skagit River development for the City of Seattle, a simple, inexpensive corona shield shown in Fig. 1 was developed. This shield is made from $\frac{1}{16}$-in. circular steel plate 15 in. in diameter. This is stamped into a saucer shape and on the flat part or the bottom of the saucer two parallel slots are stamped out so that the shield may be dropped over the clevis of the line conductor clamp. In this way no extra attachments or hardware of any kind is required to support the shield. After stamping the plate, the edges are rolled and the shield is dipped in asphalt paint and baked. This type of static shield not only distributes the electrostatic stresses equally along the insulator string but it acts as a splash plate to wet the underside of the lower insulator units. In addition there is sufficient metal to withstand several flashovers without impairing the effectiveness of the shield. The insulation on this transmission line consists of 10 insulator units in suspension, 12 units on angle turns and 14 units on dead ends.

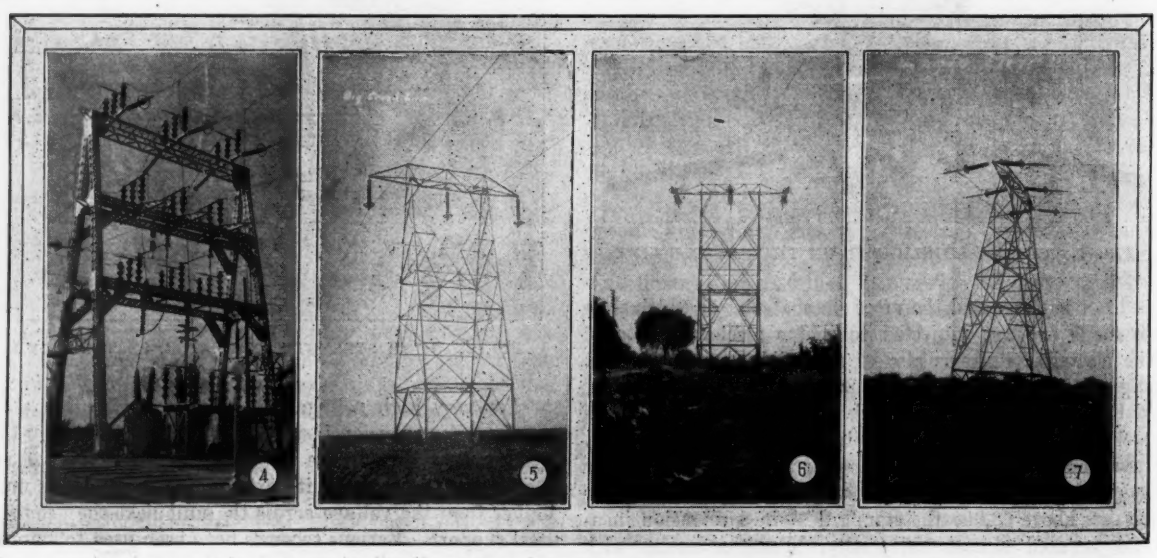
Figure 2 shows the type of insulator used on this line. It is an extra heavy duty insulator with a mechanical strength in tension of 18,000-20,000 lb. in place of the usual strength of 10,500-11,000 that is an average figure for other types.

Descriptions of a few of the outstanding transmission lines will give some ideas of the tower constructions used, the arrangement of insulators and other features of general interest. Some of these illustrate wooden tower construction and others the more usual steel arrangements.

For this Seattle line, suitable wooden poles of excellent quality were obtainable near the right of way and the cost of wooden construction worked out much cheaper than using steel with a long over-land haul from the steel mills where towers are fabricated. For the greater portion of the transmission system double wooden pole construction was utilized. Two upright wooden poles are joined together at the top by a bar of cross members suitably braced. One transmission line wire passes between the two poles, the other two lines being outside the poles.

Where the transmission line crosses the Snohomish Flats a rather peculiar construction is used in which the pole is placed in the ground in the usual way but four reinforcing poles are placed around it and fastened to it to increase the strength of the pole at the ground line by having a much larger bearing service against the ground which is very moist at this point. The normal construction of a single pole would not have sufficient security in case of breakage on the transmission line to prevent the pole from being pulled out of the moist ground.

Figure 3 shows the pole arrangement at an angle bend in the transmission line. Three individual poles are used and the insulators are attached to the side of each pole near the top, the transmission wire passing to the right of each of the poles.



FIGS. 4-7. VARIOUS TYPES OF TOWERS USED IN WESTERN UNITED

Fig. 4. Steel Frame Structure, Substation, City of Seattle. Fig. 5. Suspension Tower, 220 kv. line, Southern California Edison Co. Fig. 6. Strain Tower, 220 kv. line, Southern California Edison Co. Fig. 7. Side view of tower shown in Fig. 6.

Where this Skagit River transmission line approaches the City of Seattle the line is run along the main roadway. On either side of the road tall wooden poles are erected with a steel messenger wire hung between them and the insulator strings suspended from this steel messenger wire. The poles are high enough so that a second circuit can be placed below the first one by using similar sets of insulators hung from a second messenger wire between the side poles.

At the Seattle substation wooden poles properly guyed were used for dead end construction, these poles being used for a transmission line running at right angles to the main steel structure, shown in Fig. 4. This main steel structure is composed of two "A" frames of lattice construction with suitable lattice cross girders for the support of the rotating type disconnecting switches, the busbars and connections. The oil circuit breakers in the main incoming line stand on a concrete platform underneath the steel structure.

The Big Creek line of the Southern California Edison Co. operating at 220 kv. is one of the longest in the world and operated for ten years at 150 kv.

Figure 5 shows one of the standard suspension towers near the Vestal Substation. This transmission line utilizes an aluminum cable steel reinforced 605,000 c.m. An overhead ground wire of one-half inch Siemens-Martin steel is run above the transmission line. The length of this transmission line is 240 mi., the normal span at low altitudes is 660 ft., the normal span at altitudes above 2000 ft. is 550 ft.; the maximum span 2870 ft., the normal conductor spacing horizontally 17 ft. 3 in., normal height of crossarm — 43 ft. Weight of the standard suspension tower including the footings is 6000 lb., weight of the standard angle tower including footings 7500 lb.

Figure 6 shows one of the standard angle towers looking along the transmission line and Fig. 7 shows the same tower as seen from a point at right angle to the transmission line.

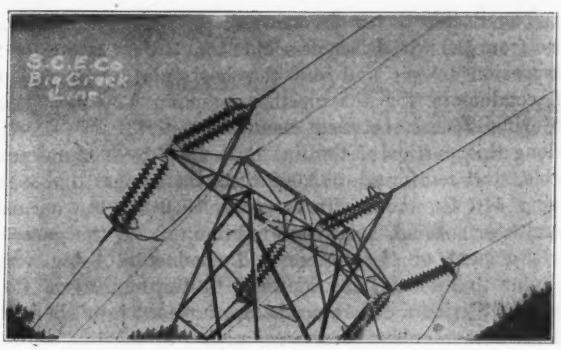


FIG. 8. INSULATOR ARRANGEMENT STRAIN TOWER, 220-KV. LINE, SOUTHERN CALIFORNIA EDISON CO.

Figure 8 gives a closeup view of the insulator arrangement at the strain towers. Two strings of insulators in parallel are used to secure the desired mechanical strength and a large static shield in the form of a ring improves the voltage distribution along these insulated strings.

At the Vaca Substation shown lattice work steel frames are used for the support of the disconnecting switches mounted above the oil circuit breakers and the high tension busbars are made in the form of line conductors strung between the steel framework.

At this Vaca Substation the 220-kv. system is tied in with the 110-kv. system through suitable transformers and the 110-kv. feeders are carried away from this substation on twin circuit steel towers as shown on Fig. 9, this picture illustrating strain towers at an angle bend in the transmission circuit.

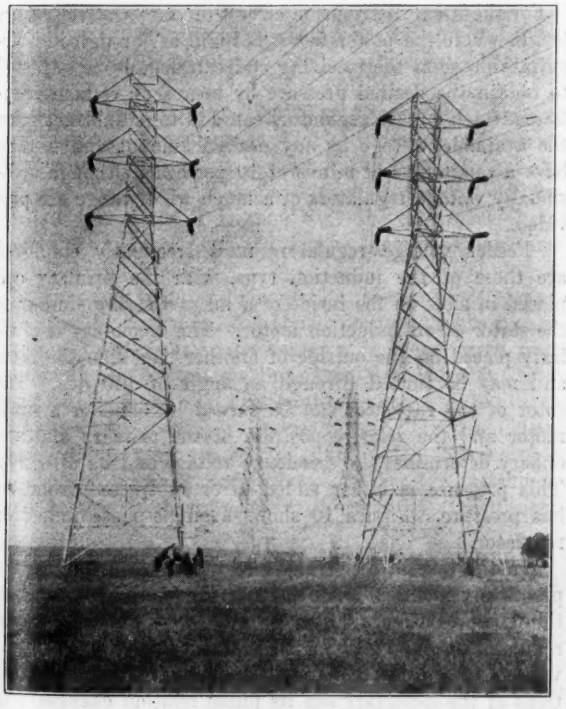


FIG. 9. 110-KV. TWO CIRCUIT TOWERS, SOUTHERN CALIFORNIA EDISON CO.

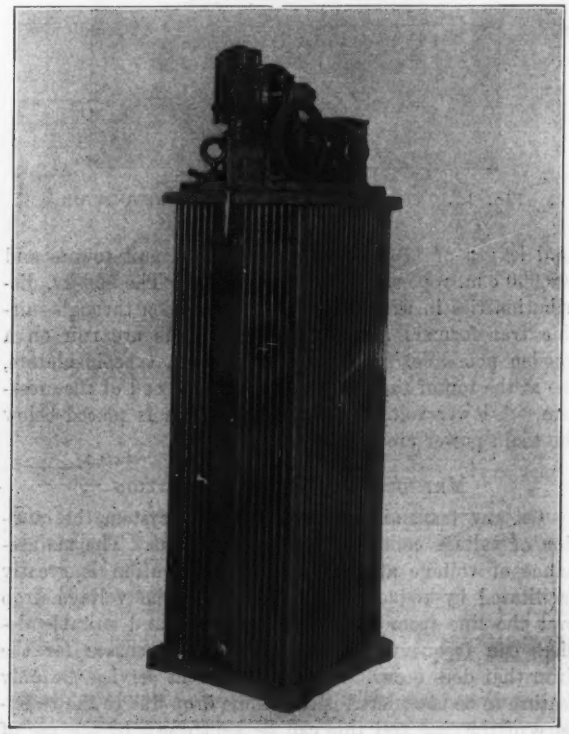


FIG. 10. SINGLE-PHASE INDUCTION REGULATOR

The Pacific Gas & Electric Co. for their transmission line from the Pitt River development utilize single circuit suspension towers and use the horizontal arrangement of conductors for the northern section of their line covering 26 mi. between Round Mountain and Cassel. Along this portion of the line the conductor is aluminum cable, steel reinforced, 518,000 c.m., the normal line span being 440 ft., the maximum span 1510 ft., the normal conductor spacing, horizontal position, 16 ft., the general arrangement of the towers and conductors being very similar to those of the Southern California Edison Co., except utilizing a different scheme of graded insulation for the insulators. The remaining section of the line with a total length of 176 mi. utilizes double circuit towers and 500,000 c.m. rope stranded copper cable. The 220-kv. distribution ties in with the 66-kv. distribution through suitable transformers and the 66-kv. circuits are run on a wooden pole line. This line utilizes pin type insulators, one at the top of the pole and one at each end of the crossarm. A lower voltage distribution circuit is placed below the main power crossarm.

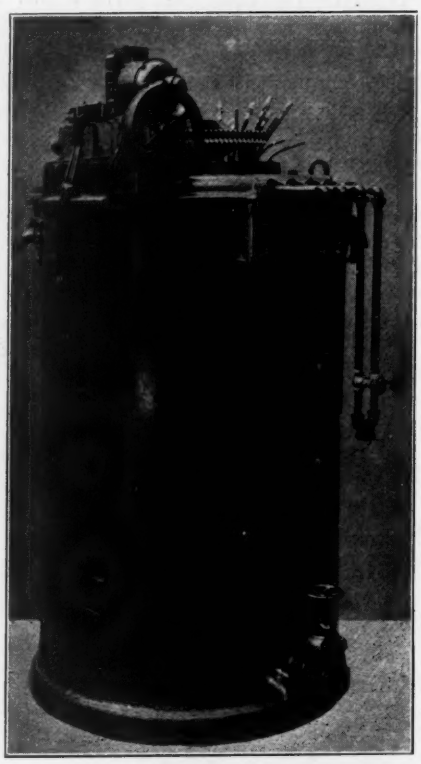


FIG. 11. THREE-PHASE INDUCTION REGULATOR

Methods of Voltage Regulation

On any transmission or distribution system the question of voltage control is highly important. The maintenance of voltage at the point of distribution is greatly facilitated by reducing to a minimum the voltage drop over the line from the point of supply, and suitable devices can frequently be installed to compensate for the drop that does occur. For direct-current service the only feature to be considered is the ohmic drop due to the resistance of the line and this can be kept down by the use of large conductors. An economical point is, however, reached where the increased cost of conductor and possibly the use of larger insulators and heavier supports is not warranted by the reduction in the voltage drop and the actual loss in the transmission line. The most economical point as stated in the "Kelvin Law" is usually found when the cost of the power lost on the line is the same as the interest on the money invested in the line.

For direct-current service over long lines for railway work use has occasionally been made of boosters to raise the voltage in an amount proportional to the drop in the transmission line so as to maintain essentially constant voltage at the point of distribution independent of the load. As a rule, however, substations fed from a.c. lines can be so located along the railway as to maintain a suitable d.c. voltage on the line.

In alternating-current transmission, particularly for long distances at high voltage, other questions beside the resistance of the line have to be seriously considered. The reactance of the line for the usual frequency employed is often of considerably higher value than its resistance, so that the reactive drop, particularly due to a load of low power factor is often much greater than the resistance drop. Where extremely long lines are used at high voltage, or where cables are employed, the static capacity of the line also needs to be carefully considered.

A condition frequently met on a long transmission line is that at times of light load the substation voltage will be higher than that of the generating station. This effect, known as the "Ferranti Effect," was first noted in connection with underground cable circuits operated at 10,000 v. in London and it is frequently experienced in connection with long high tension lines. It is due to the static capacity of the line, this in turn depending on the relative location of transmission line wires, their distance from ground, etc., on overhead lines, and the characteristics of the cables for underground lines.

For the usual distribution circuit of comparatively short length where the power factor is high, as for lighting circuits, voltage at the receiving end can usually be adjusted to obtain the desired pressure by means of voltage regulators. Such voltage regulators can add to or subtract from the available voltage by any desired amount and usually have a range plus or minus of 10 per cent, although occasionally voltage regulators of a much wider range are provided.

Feeder voltage regulators most frequently employed are those of the induction type, with the primary coil placed in slots on the inside of a magnetic ring similar to the stator of an induction motor. The secondary is similarly placed on the outside of another ring like the rotor and may be turned through an angle of 180 deg. The rotor of the regulator can be turned by hand or a small motor and the relative position of the primary and secondary determines the secondary voltage and its direction. This pressure is either added to or subtracted from the bus pressure. Figure 10 shows a single-phase induction regulator.

In the case of a polyphase regulator the windings are practically identical with those of the wound rotor induction motor. Figure 11 shows a three-phase water-cooled regulator in its tank. With the polyphase regulator the voltage induced in the regulator is the same in all positions of the secondary but its phase relation changes with this relative location so that the voltage of the regulator is combined with the main voltage at various angles, so

that the resultant voltage is capable of being adjusted through the desired percentage up and down.

While most of the induction regulators have been made for indoor service, pole line type induction regulators are available. Where it is necessary to compensate for reactive drop as well as ohmic drop due to supplying a load of low power factor, the use of condensers, either of the static type or the synchronous type, should be carefully considered.

With the static type of condenser, the power factor at the point of distribution can be brought back to unity if desired, although it is not customary to correct power factor to more than 90—95 per cent. With the wattless kv.a. of the low power factor load taken care of by means of a condenser the transmission lines to this point of distribution carry only the real energy load and are only subject to the ohmic drop.

On the usual transmission line, particularly if the static capacity of the line is appreciable, synchronous condensers, or synchronous phase modifiers located at the main distribution points can usually be employed to advantage. At times of light load the synchronous condenser can be operated with the minimum excitation so as to compensate for the charging kv.a. of the transmission line and can in this way hold down the voltage at the receiving end to the normal amount. As the load comes on, the excitation of the frequency changer can be automatically varied so that at the point when the reactive kv.a. of the load would just form a balance for the leading reactive kv.a. in the transmission line the synchronous condenser would so operate as not to effect the voltage at the receiving station.

As the load still further increases, the excitation of the synchronous condenser would be increased in such a manner as to supply all of the reactive kv.a. needed by the load with the exception of that already furnished, due to the static capacity of the transmission line. The synchronous condenser then, within the limit of its capacity, will maintain the voltage constant at some predetermined amount at the receiving station while the load on that station varies from zero up to its maximum.

Practically all of the large long distance transmission lines in operation are provided with synchronous condensers at the receiving end, and occasionally at intermediate points to maintain the proper voltage at such points.

On moderate voltage distribution of large capacity the current that will tend to flow over the distributing cables in case of a short is liable to reach disastrous proportions and may tend to wreck any regulators or other equipment in that particular circuit.

Illumination Design for Turbine Rooms

PROPER LIGHTING OF TURBINE ROOMS REQUIRES NOT ONLY CORRECT LOCATION OF LIGHTING UNITS BUT ALSO A SELECTION OF THE PROPER TYPE OF UNIT. BY DAVIS H. TUCK*

DAY AND NIGHT are much the same in the operation of the electric power plant. One of the most necessary but often neglected adjuncts to safe and efficient operation is high intensity illumination. During the day, this is largely accomplished by the provision of ample window area; but in almost every plant, there are places, some of them containing very important pieces of apparatus, that must be artificially lighted 24 hr. a day.

In the routine operation of a power plant, the work never stops. Sometimes a plant is taken off the line and shut down but that does not mean that the operators lock up and go home. The periods of shut-down are their busiest times, for it is then that the apparatus that is dangerous to touch or approach when energized, is cleaned, adjusted and repaired.

When the plant is in operation, there are switchboard readings to be taken, the station reports made up, records and log-books to be kept and a close watch maintained on all instruments and gages, so that instant action may be taken at the first hint of abnormal conditions, before actual breakdown takes place. The switchboard must therefore have adequate illumination without objectionable shadows or lamp images so that the instruments may be read from any angle with certainty and precision.

SELECTION OF PROPER LIGHTING UNITS

Turbine room design makes it necessary to locate the lighting units over the craneway at heights varying between 30 and 100 ft. above the floor. Steel reflectors such as the deep bowl type or the standard dome types are not adapted for use in such locations because they are of the extensive type and a large portion of the available light is lost, in the case of the deep bowl type, by absorption in the reflector and on the side walls and in the case of the dome type, on the side walls. Both of these types of reflectors have an absolute cutoff below the horizontal and give a gloomy appearance to the upper portion of the turbine room.

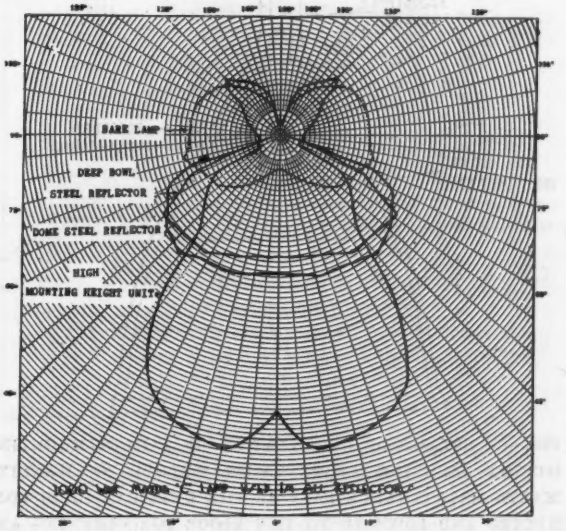


FIG. 1. COMPARATIVE CANDLEPOWER DISTRIBUTION CURVES OF VARIOUS REFLECTORS, ALL USED WITH 1000 WATT BARE MAZDA C LAMP

It is to be noted that the candlepower values in the effective zone for high mounting unit (0-30 deg.) are more than double those of either the deep bowl, steel or the dome reflectors, and that the dome type has slightly greater downward candlepower values than the deep bowl type reflector.

*Electrical Engineer, Holophane Co.

It is not generally realized that the deep bowl steel reflector is not an intensive type reflector and that the dome type reflector actually gives greater downward candlepower values than the deep bowl type. The comparative distribution curves shown in Fig. 1 illustrate this point. It will be noted from this chart that the deep bowl steel reflector is less intensive than the dome type and that neither is suitable for high mounting height use. The third curve represents the light distribution from a high-mounting-height unit, which has been designed especially for this use. It will be seen from Fig. 1 that the large increase in downward candlepower is made by redirecting the 30-90 deg. flux of light, which is ineffective for high mounting into the 0-30 deg. zone.

Figure 2 shows a plan and elevation of a typical hydro-electric plant with the lighting units located. There are 12 high-mounting-height units used with 1000 w. clear mazda lamps hung 36 ft. from the floor. This represents 2.2 w. per sq. ft. and subsequent lighting tests made after the system had been in operation 3 mo., showed an average illumination of 14 ft. candles. This represents an efficiency of utilization of 32 per cent after a depreciation of 3 mo. This efficiency of utilization has been checked by actual measurement in other stations and may be used for calculations for the design of lighting systems using a high-mounting-height unit in turbine rooms.

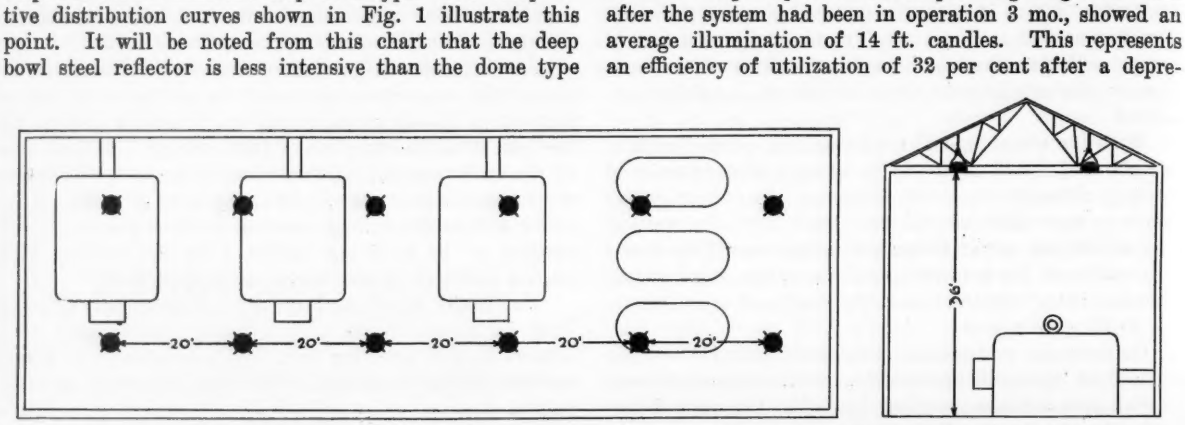


FIG. 2. PLAN AND ELEVATION OF A TYPICAL HYDRO-PLANT, SHOWING THE LOCATION OF TURBINES, TRANSFORMERS AND LIGHTING UNITS

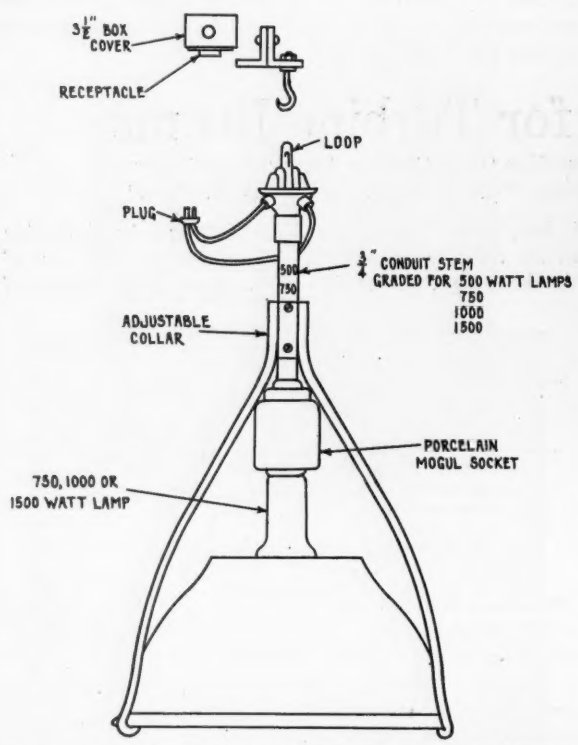


FIG. 3. DETAILS OF INSTALLATION OF A HIGH MOUNTING HEIGHT LIGHTING UNIT. THIS METHOD OF HANGING MAKES MAINTENANCE EASY AS THE UNIT CAN BE DISCONNECTED AND LOWERED TO THE FLOOR FOR CLEANING AND RELAMPING

FIG. 4. EXTERIOR NIGHT VIEW OF A HYDRO-PLANT, ILLUSTRATING THE ADVERTISING VALUE OF A WELL-LIGHTED STATION

The illumination measured on the vertical faces of the electrical measuring instruments on the switchboards was 5.5 ft. candles at the top of the board and 5 ft. candles at the bottom of the board. In the station proper, the highest foot candle intensity was only 7 per cent greater than the lowest intensity. The details of installation represents a departure from the ordinary method of hanging lighting units. The "T" of the roof truss is drilled and a ⅜-in. iron hook is bolted into position, the Lighting Unit is hung on this hook and the electrical connection is made by plugging into the receptacle.

In Fig. 3 are shown details of the installation. With this method of hanging, cleaning and lamp renewals are made by one man riding on the crane, who disconnects one unit and lowers it to the floor, where a second man passes up a clean unit and then cleans the dirty one to

be passed up for the next location. This maintenance procedure reduces the danger incident to cleaning lighting units mounted at excessive heights without resorting to expensive disconnecting hangers. The advertising value of a brightly lighted power plant should not be overlooked.

Not only is adequate lighting required in the vicinity of the machinery and control equipment, but in the hydro-electric plant the forebay must be kept well lighted, so that water and ice conditions may be observed and if necessary to clean trash racks, or remove ice or floodwood in the night, the hazards inseparable from this part of the hydro-electric plant may be plainly visible.

Properly designed lighting units to minimize or eliminate glare and at the same time to provide brilliant illumination of every part of the plant (not neglecting those parts that are never visited), will greatly increase the efficiency of the work done and will go far to prevent accidents to men, equipment and service by making the plant safe, attractive and convenient for the men who must keep the wheels going 24 hr. a day, and 365 days in the year.

Essentials of Correct Boiler Water Conditioning

STANDARD MUST BE DEVELOPED FOR CONDITIONS INSIDE THE BOILER INSTEAD OF DEGREES OF HARDNESS, MEASURED ON THE OUTSIDE. BY R. E. HALL*

FOR YEARS power plant engineers have been basing their attempts to control scale prevention in boiler water on certain specifications for degrees of hardness. What is really wanted, however, is clean evaporating surfaces and, when this is made the criterion, chemists will base their new standards on the conditions occurring in concentrated boiler water itself.

There is much more to the problem, however, than clean surfaces. Corrosion in feed lines, economizers, and the boiler is a function of the condition of the water in contact and must be controlled. Steam line and turbine blading deposits—the result of wet steam—must be obviated by the system of conditioning. By the chemical treatment employed, the amount and character of non-condensable gases in the steam must be controlled in accordance with the intended use of the steam. The responsibility in boiler water conditioning does not end with the entrance of the water into the boiler, but with the passage from the boiler nozzle of steam, whose dryness and purity are defined by the purpose for which it is intended.

In Fig. 1 is shown a diagram of the surfaces coming in contact with the water and gives a clearer conception of the scope of the conditioning processes. From this diagram the problems of boiler water conditioning, therefore may be outlined as follows:

1. Prevention of scale formation on surfaces.
   (a) In contact with water but at which no evaporation occurs, and
   (b) At which evaporation is occurring.
2. Prevention of corrosion on surfaces (a) and (b) of (1).
3. Selection of chemical treatment on the basis of non-condensable gases that are permissible in the steam.
4. The control of sludges and soluble salts in the boiler water.

Emphasis has been placed upon the exactness with which any formation of scale can be controlled. The following expression serves as a general criterion for evaporating surfaces:

Concentration in the boiler water of chemical used in treatment. = { Function of (a) the operating pressure, and (b) concentration of sulphate (SO_4) in the boiler water.

This expression makes no limitations regarding the type of feed water to be used, or as to whether the water be conditioned by the use of evaporators, by pre-treatment systems as lime and soda ash or the base-exchange proc-

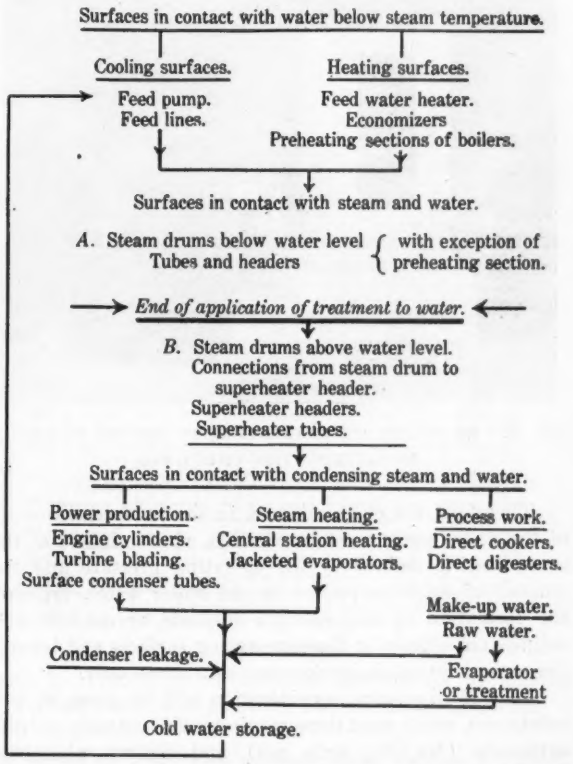


FIG. 1. THIS DIAGRAM SHOWS THE VARIOUS SURFACES WITH WHICH BOILER WATER COMES IN CONTACT

esses, or by direct introduction into the boiler water of the chemical used in treatment. Neither does it specify whether the sludges produced shall be removed by filtration of the feed water, by filtration of boiler water, or by blowdown. It is a generalized statement of the fact that the two major factors to be considered in prevention of scale formation on the evaporating surfaces are operating pressure and the sulphate concentration in the boiler water.

In order to define the term "chemical used in treatment," it is necessary to understand two principles gov-

*Physical Chemist, U. S. Bureau of Mines. Abstract of a paper presented at Midwest Power Conference, Chicago, Jan. 26-30, 1926.

erning adherent scale formation on the evaporating surfaces. Evidence in proof of their validity has been presented elsewhere and we need only state them briefly in this discussion as follows:

1. Adherent scales that grow in thickness are formed by deposition from the boiler water directly on the surfaces where found when the boiler is opened. This may be called deposition *in situ*, because the crystals responsible for the growth of the scale have never been present as individual particles free to follow the flow of the boiler water and be deposited in haphazard fashion on the surfaces.

There are three substances that deposit from the boiler water in this manner—namely, calcium sulphate, and calcium and magnesium silicate.

2. The solubility of substances that form adherent scales decreases with temperature increase; vice versa, those substances which separate from the boiler water as sludge increase in solubility with temperature increase.

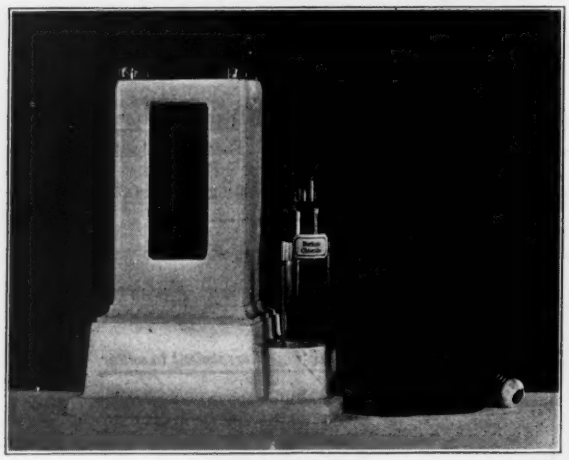


FIG. 2. SULPHATE CONCENTRATION IN BOILER WATER IS MEASURED WITH THIS GAGE

Therefore, the chemical used in the final conditioning of the boiler water must be one that, if maintained at the concentration defined by the operating pressure and the amount of sulphate present in the boiler water, prevents the formation of any calcium sulphate or calcium and magnesium silicate at the evaporating surfaces and insures the separation of sludge-forming substances only.

In this discussion consideration will be given to two substances, which meet these requirements—namely, sodium carbonate (Na_2CO_3, soda ash) and sodium phosphate (Na_3PO_4). The use of sodium silicate is excluded because calcium and magnesium silicate are responsible for adherent scale formation. Any type of colloidal treatment is evidently out of question in view of the deposition of adherent scale *in situ*. Sodium carbonate and phosphate have been specified because they can be purchased more cheaply than other carbonates or phosphates. It must be recognized, however, that they are used because of their available carbonate (CO_3) or phosphate (PO_4) content, and that other carbonates or phosphates, as for example, the potassium compounds might be used if they were cheaper or if a special reason existed for their use. Thus barium carbonate ($BaCO_3$) may be used in preference to sodium carbonate, even though the cost is greater, in case it is necessary to decrease the concentration of soluble solids in the boiler water other than by blowdown.

Regardless of any pre-treatment which may have been given to the feed water, the essential relation to maintain in the boiler water is expressed thus when soda ash is used for the purpose:

(1) $CO_3 = K_1$ (at operating pressure p) $\times SO_4$

If sodium phosphate is used, then the expression becomes

(2) $PO_4 = K_2$ (at operating pressure p) $\times \frac{3\ SO_4}{2} \times \frac{D\ (SO_4)}{2}$

In these expressions CO_3, PO_4, and SO_4 are preferably measured in parts per million, although grains per gallon may be used as well. K_1 and K_2 are specific for CO_3 and PO_4 respectively, and are constants for a definite operation pressure p but vary with variation of the operating pressure. D refers to the relation of ionic to total SO_4 in the boiler water and is a function of the operating pressure and of the concentration of SO_4.

What Happens When Soda Ash Is Used

As an example of conditioning with soda ash, assuming a pressure of 150 lb. gage, $K_1 = 0.0883$ if concentrations are expressed as parts per million. Thus, if the sulphate concentration in the boiler water is 1000 p.p.m., the concentration of CO_3 therein must be slightly more than

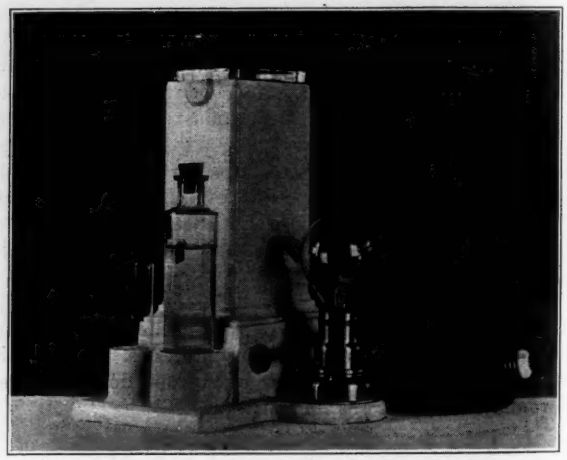


FIG. 3. THIS IS A REAR VIEW OF THE SAME GAGE SHOWING SLOT ILLUMINATED BY AN ELECTRIC LIGHT

88 p.p.m. to insure absence of adherent scale growth. If the sulphate is but 500 p.p.m., then the maintenance of a CO_3 concentration of 50 to 75 p.p.m. in the boiler water is sufficient. As a rule, it is best to determine in each plant what sulphate concentration corresponds to economical blowdown practice. Thereafter, the maintenance of this sulphate concentration serves to control blowdown and defines a constant concentration of CO_3 which must be present in the boiler water.

Simplicity of this control is evidenced by the apparatus necessary in the boiler room for determining the SO_4 and CO_3 concentrations. Figures 2 and 3 show the apparatus used for determination of the SO_4 concentration. Into the glass jar is introduced a sample of filtered boiler water (10 to 100 c.c. according to the amount of SO_4 therein), and 10 c.c. of acidified barium chloride solution is added whereupon a finely divided white precipitate is formed.

Sulphate-free water is next added until a brightly illuminated slit at the rear of the specimen jar becomes distinctly outlined to the eye. The visibility of the slit represents a definite dilution of the contents of the jar and the quantity of SO_4 in the boiler water is read directly in parts per million from the scale etched on the jar.

Figure 4 shows the apparatus for determining CO_3. A 100 c.c. sample of boiler water filtered in a and automatically measured in b with a few drops of phenolphthalein indicator added is treated with acid from the large barrel of the burette until the red color of the indicator disappears. The addition of a few drops of bromphenol blue indicator now colors the sample blue. Acid is added from the small barrel of the burette until the blue changes to green. The number of cubic centimeters of acid drawn from the small barrel multiplied by a factor (by 20 in case 1/30 normal acid was used) gives directly the CO_3 concentration of the boiler water in parts per million.

When soda ash is used as conditioning chemical at the operating pressure under consideration, the evaporating surfaces usually become covered with a thin, porous film consisting largely of calcium carbonate unless unnecessarily high blowdown is resorted to. It is characteristic of this film that it does not increase in thickness, unless the concentration of CO_3 in the boiler water is deficient. It is probable that this film, because of its ready permeability

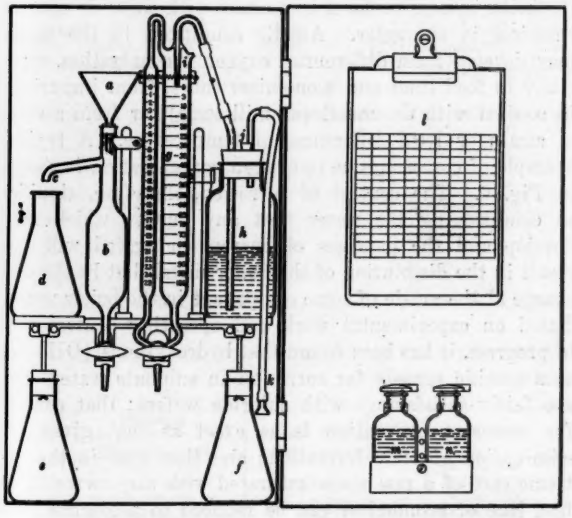


FIG. 4. FOR DETERMINING ALKALINITY IN BOILER WATERS, THIS APPARATUS IS USED

by water, is very slightly detrimental to the transfer of heat to the boiler water and it may offer some protection against corrosion, although this is considered doubtful.

Use of a Phosphate Eliminates Calcium Film

If one desires to be free from the calcium-carbonate film, the conditioning of the boiler water may be accomplished by means of PO_4. The character of the sludge produced is quite different and the film on the evaporating surfaces is not in evidence. The cost in this case is about fourfold that when soda ash is used.

For the operating pressure of 160 lb. gage and the use of PO_4 in conditioning the boiler water

$$K_2 = 0.000164$$

when concentrations are expressed as parts per million. In the expression giving the relation of PO_4 to the SO_4 concentration of the boiler water, however, is found the term D relative to the ratio of ionic to total SO_4 in the water. This ratio changes with change in concentration of the SO_4; at the operating pressure under discussion for 1000 p.p.m. of SO_4, D = 0.65; for 2000 p.p.m. of SO_4, D = 0.59. Substituting these values in equation (2) we find that for a concentration of 1000 p.p.m. of SO_4 in the boiler water, the essential concentration of PO_4 necessary to prevent adherent scale formation is slightly more than 4 p.p.m., and for 2000 p.p.m. of SO_4 slightly more than 11 p.p.m. It will be satisfactory, therefore, under the conditions stipulated, to maintain a phosphate concentration of from 15 to 25 p.p.m. in the boiler water.

Apparatus for determining the SO_4 concentration has been described. That for determining PO_4 may be an adaptation of Fig. 4.

Relation Between Chemicals Used and the Operating Pressure

It is evident from equation (1) that the maintenance

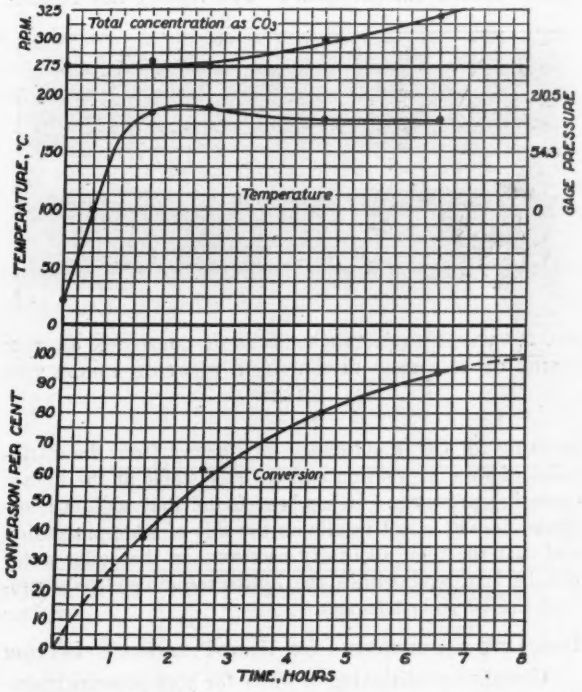


FIG. 5. CURVES SHOW RATE OF CONVERSION OF SODIUM HYDROXIDE TO CARBONATE UNDER BOILER PRESSURE

of scale-free conditions depends upon keeping a definite supply of CO_3 in the boiler water. In case conditions arise such that the necessary CO_3 concentration cannot be maintained, then it is no longer feasible to use soda ash as the conditioning chemical.

At boiler temperatures soda ash decomposes according to the reaction

$$Na_2CO_3 + H_2O = 2\ NaOH + CO_2$$

and the rate, as shown in Fig. 5, depends upon operating pressure and the boiler rating. These, in conjunction with the concentration of SO_4 determine the proper CO_3 concentration.

Thus higher operating pressures are characterized by more rapid decomposition of CO_3 and at the same time by the necessity for maintaining higher CO_3 concentration,

since the value of K_1 is greater at higher than at lower operating pressures. In a boiler operating at low rating, it may be possible to maintain the necessary amount of CO_3 in the boiler water, while in the same boiler at high rating the more rapid decomposition of CO_3 may render such maintenance impracticable unless the blowdown is of uneconomical proportions. Again, if two boilers are operating at the same pressure and rating, but the feed water for one is high and the other low in sulphate content in the boiler receiving the high sulphate water, it may be possible to maintain the necessarily high CO_3 concentration, even with large blowdown, while in the one receiving the low sulphate water it may be a simple matter.

When using soda ash, the basic cause for these troublesome limitations lies wholly in its decomposition into caustic soda and carbon dioxide. Also, apart from the uncertainty of maintaining satisfactory CO_3 concentrations, the high caustic alkalinity developed in its decomposition makes it impossible at higher operating pressures to keep within the alkalinity-sulphate ratio recommended against caustic embrittlement. The remedy lies in substituting for CO_3 a substance satisfactory from the standpoint of scale prevention and entirely stable at the higher operating pressures. It has been found that sodium phosphate gives excellent results on the side of scale prevention and that the total alkalinity necessary in the boiler water can be kept well within the limits recommended to prevent caustic embrittlement.

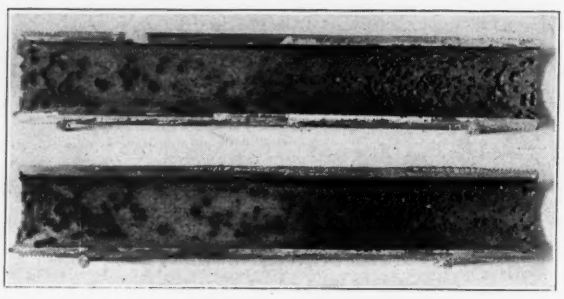


FIG. 6. THIS SHOWS THE EFFECTS OF CORROSION ON THE INSIDE OF THE FEED PIPE WHICH PROJECTS INSIDE THE BOILER

Complete Conditioning for High-Pressure Operation

Complete conditioning of water for high-pressure operation may be effected as follows: If the make-up water is evaporated and the only impure water entering the boiler consists of the condenser leakage, then conditioning the boiler water with phosphate is the only chemical control necessary. If the make-up water is not evaporated, and is of some magnitude, then economy demands a pre-treatment—with lime and soda ash for any water, or by a base-exchange process if the water does not contain temporary hardness—followed by the final conditioning of the boiler water with phosphate. In the pre-treatment, however, any addition of excess chemical must be avoided, else detrimental concentrations of caustic alkalinity will develop in the boiler water. If it is deemed desirable to limit the amount of soluble solids in the boiler water and the feed water is one that contains sulphate, a variation in pre-treatment may be made by using barium carbonate in the softener in place of sodium carbonate, thus removing much of the sulphate as well as the calcium. In any event, however, the final control of the boiler water must be based on the use of a stable substance such as phosphate.

Methods of Preventing Scale Formation on Feed Water Lines and Preheating Sections

Scale prevention on the surfaces that are in contact with water but at which evaporation is not occurring is much simpler than on evaporating surfaces as there is only one main constituent in these scales, namely, calcium carbonate; deposition of insoluble solid material occurs by reason of supersaturation throughout the body of the water and not at the surfaces alone, as in the case where evaporation is occurring; and there is no decomposition of the chemical used in treatment.

In order to prevent scale formation on these surfaces it is necessary that no bicarbonate remain in the water and it is advisable that a small concentration of caustic soda and loose crystals of suspended calcium carbonate be present. If the water has been correctly treated externally and sufficient time given for complete reactions to occur, no trouble should be experienced from this type of scale. If, however, this is not the case, the formation of a carbonate scale can be prevented by re-circulating water from the boiler through the feed lines or the pre-heating sections.

Control of Corrosion Must Be Electro-Chemical

In general, it seems quite certain that any corrosion of the boiler system surfaces in contact with water is electro-chemical in character. Anodic conditions in the metal may develop from differential oxygen concentration, especially in feed lines and economizer tubes, from impurities in contact with the metal (as mill scale), or from a state of strain or local differences of temperature. A typical example of corrosion due to oxygen concentration is shown in Fig. 6. The control of corrosion, therefore, signifies so conditioning the water that any anodes which may develop and the passages of current generated will not result in the dissolution of the boiler metal, but in the discharge at the anode of some component in the boiler water. Based on experimental work and operating control now in progress, it has been found that hydroxyl ions (OH) act as a specific remedy for corrosion in sulphate waters and are fairly satisfactory with chloride waters; that control for corrosion prevention is as exact as that given for elimination of scale formation; and that even in the extreme case of a raw water saturated with air, corrosion of feed line or economizer can be reduced to negligible proportions.

Control of Non-Condensable Gases in the Steam

If the feed water contains dissolved air, much of this is removed in the feed water heater or the deaerator. Wherever the presence of CO_2 in the steam is detrimental, all carbonates, so far as possible, should be kept from the boiler water. If the make-up water is evaporated, direct control of the boiler water with a phosphate limits the quantity of carbon dioxide to the amount derived from condenser leakage. If the feed water is given a primary treatment with lime and soda ash, it is necessary to avoid all excess of treatment and use a secondary control with phosphate. If the feed water contains temporary hardness and is treated by a base-exchange process, it may be necessary to pre-treat with lime, or to remove the excess sodium bicarbonate in the water after treatment by the use of acids or other means and the final control must be established by means of a phosphate (PO_4).

Public Utilities Use Nearly 1½ T. of Coal a Second in 1925

TOTAL ANNUAL OUTPUT of electricity by public-utility power plants in 1925 was 65,801,000,000 kw-hr., an increase of 11.5 per cent over the output for 1924. Of this quantity, about 34 per cent was produced by the use of water power, a slight increase over the percentage for 1924. It would have required the consumption of 23,000,000 t. of coal to generate this 34 per cent, according to the annual report just issued by the U. S. Geological Survey on the annual production of electricity and consumption of fuels by public-utility power plants in 1925.

The amount of coal consumed in producing electricity in 1925 was only 7 per cent greater than in 1924. The amount of oil was 38 per cent less and the amount of gas was 4 per cent less than in 1924. Although the oil consumed amounted to more than 10,000,000 bbl. and the gas to nearly 50,000,000,000 cu. ft., coal represented nearly 90 per cent of all the fuel used by electric power plants.

TABLE I. PRODUCTION OF ELECTRICITY, IN KILOWATT-HOURS, BY PUBLIC-UTILITY POWER PLANTS IN 1925

United States and Sections	Total	Water Power	Fuel Power
United States	65,801,158,000	22,322,180,000	43,478,973,000
New England	4,806,715,000	1,630,547,000	3,176,168,000
Middle Atlantic	18,283,765,000	5,168,537,000	13,115,228,000
East North Central	15,698,844,000	1,621,694,000	14,077,150,000
West North Central	4,248,913,000	1,317,412,000	2,931,501,000
South Atlantic	6,266,524,000	1,668,220,000	4,598,304,000
East South Central	2,640,371,000	1,054,214,000	1,586,157,000
West South Central	2,199,606,000	30,591,000	2,169,015,000
Mountain	3,123,025,000	2,603,539,000	519,486,000
Pacific	8,563,395,000	7,257,426,000	1,306,969,000

Total output by use of wood, 245,700,000 kilowatt-hours (included in above figures)

TABLE II. CONSUMPTION OF FUEL BY PUBLIC-UTILITY POWER PLANTS

United States and Sections	Coal (Net tons)	Oil (Barrels)	Natural gas M cubic feet
United States	40,173,742	10,254,195	46,480,743
New England	2,728,949	925,711	0
Middle Atlantic	12,087,028	302,340	227,642
East North Central	14,530,121	55,080	6,539,144
West North Central	3,650,994	1,146,141	5,383,539
South Atlantic	3,999,623	1,717,450	577,045
East South Central	1,753,579	149,612	50,465
West South Central	669,048	3,191,515	23,202,088
Mountain	691,254	237,934	150,772
Pacific	63,146	2,528,412	10,350,048

TABLE III. ANNUAL PRODUCTION BY PUBLIC-UTILITY POWER PLANTS IN THE UNITED STATES, 1919-1925

Year	Total		Water Power			Fuel Power		
	Kilowatt-hours	Change from previous year (per cent)	Kilowatt-hours	Per cent of total	Change from previous year (per cent)	Kilowatt-hours	Per cent of total	Change from previous year (per cent)
1919	38,921,000,000	----	14,606,000,000	37.5	----	24,315,000,000	62.5	----
1920	43,555,000,000	+11.9	16,150,000,000	37.1	+10.6	27,405,000,000	62.9	+12.7
1921	40,976,000,000	- 5.9	14,971,000,000	36.5	- 7.3	26,005,000,000	63.5	- 5.1
1922	47,659,000,000	+16.3	17,206,000,000	36.1	+14.9	30,453,000,000	63.9	+17.1
1923	55,674,000,000	+16.8	19,348,000,000	34.8	+12.4	36,327,000,000	65.2	+19.3
1924	59,014,000,000	+ 6.0	19,969,000,000	33.8	+ 3.2	39,044,000,000	66.2	+ 7.5
1925a/	65,801,000,000	+11.5	22,322,000,000	33.9	+11.8	43,479,000,000	66.1	+11.4

TABLE IV. ANNUAL CONSUMPTION OF FUEL BY PUBLIC-UTILITY POWER PLANTS IN THE UNITED STATES, 1919-1925

Year	Coal		Fuel Oil		Gas	
	Short tons	Change from previous year (per cent)	Barrels	Change from previous year (per cent)	M cubic feet	Change from previous year (per cent)
1919	35,100,000	----	11,050,000	----	21,406,000	----
1920	37,124,000	+ 5.8	13,123,000	+18.8	24,702,000	+15.4
1921	31,585,000	-14.9	12,045,000	- 8.2	23,722,000	- 4.0
1922	34,179,000	+ 8.3	13,197,000	+ 9.6	27,172,000	+14.5
1923	38,954,000	+14.0	14,679,000	+11.2	31,433,000	+15.7
1924	37,556,000	- 3.6	16,630,000	+13.3	48,443,000	+54.1
1925a/	40,174,000	+ 7.0	10,254,000	-38.3	46,481,000	- 4.1

TABLE V. AVERAGE CONSUMPTION OF COAL PER KILOWATT-HOUR BY PUBLIC-UTILITY PLANTS IN THE UNITED STATES, 1919-1925

Year	Output by the use of fuel b/ (Kilowatt-hours)	Change from previous year (per cent)	Net tons	Consumption of coal and its equivalent in other fuels c/		
				Change from previous year (per cent)	Pounds per Kilowatt-hour	Percentage of 1919 rate
1919	24,176,000,000	----	38,880,000	----	3.2	100
1920	27,248,000,000	+12.7	41,420,000	+ 6.5	3.0	94
1921	25,863,000,000	- 5.1	35,240,000	-15.0	2.7	84
1922	30,240,000,000	+16.9	38,000,000	+ 7.8	2.5	78
1923	36,092,000,000	+19.4	43,522,000	+14.5	2.4	75
1924	38,808,000,000	+ 7.5	43,130,000	- .9	2.2	69
1925a/	43,231,000,000	+11.4	44,700,000	+ 3.6	2.1	66

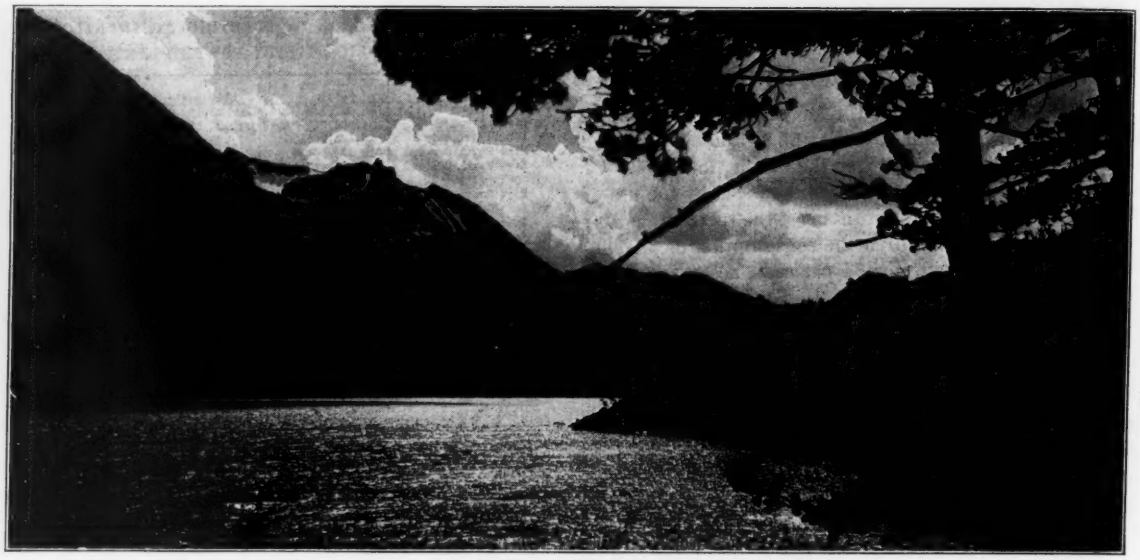
a/ Preliminary and subject to revision.
b/ Coal, oil, gas.
c/ 1 ton coal = 4.2 bbls. oil = 22,000 cu. ft. gas (approx.)

The coal plus the coal equivalent of the oil, gas, and wood used in the generation of electricity by public-utility plants in 1925 amounted to about 45,000,000 t. or an average of nearly 3000 lb. a second or 100 carloads an hour throughout the year.

Gain in efficiency in the use of fuel continued in 1925, as there was a decrease of about 0.1 lb. in the average consumption of coal per kilowatt-hour, compared with the rate of 1924. This apparently small gain amounts to more than 2,000,000 t. of coal for the year.

The information in the accompanying tables is based on the reports of the production of electricity and consumption of fuel published monthly by the Interior Department through the Geological Survey. The output of commercial and municipal central stations, as well as electric railway plants, is included in these reports. Copies of this report may be obtained of the Director, U. S. Geological Survey, Washington, D. C.

THE NEW ENGLAND POWER ASSOCIATION has purchased the Grafton County Electric Light & Power Co., which also owns the assets of the Lebanon Electric Light & Power Co. and the Mascoma Electric & Gas Co., all in New Hampshire. The assets of the companies exceed $1,000,000 with an additional $871,975 in plant investment.



Montana Power Co. Completes Mystic Lake Plant

BLASTING OF TUNNEL INTO LAKE, PIPE LINE CONSTRUCTION, AND WELL-DESIGNED PLANT ARE FEATURES OF RECENT HYDRO DEVELOPMENT. BY A. D. STEWART* AND M. E. BUCK†

IN MANY WAYS the Mystic Lake hydro-electric power plant of the Montana Power Co. is an outstanding development. During its construction unusual hazards and difficulties had to be overcome; the tapping of a lake by driving a 6 ft. by 7 ft. tunnel, 1000 ft. long and 48 ft. under the surface, and the blasting of a bench 12 ft. wide along the side of Beartooth Mountain were only two of the problems that were successfully solved. In addition, it is the only one of this company's high head plants that requires impulse type wheels.

Electrification of the Montana coal mines, most of which are located in the eastern part of Montana, and all of which are purchasing power from the Montana Power Co., coupled with the desire to furnish better service in the eastern part of their territory, induced the company to begin in 1922 on the addition of a generating station to that part of their system.

*Westinghouse Electric & Mfg. Co., Butte, Mont.
†General Superintendent, Montana Power Co.

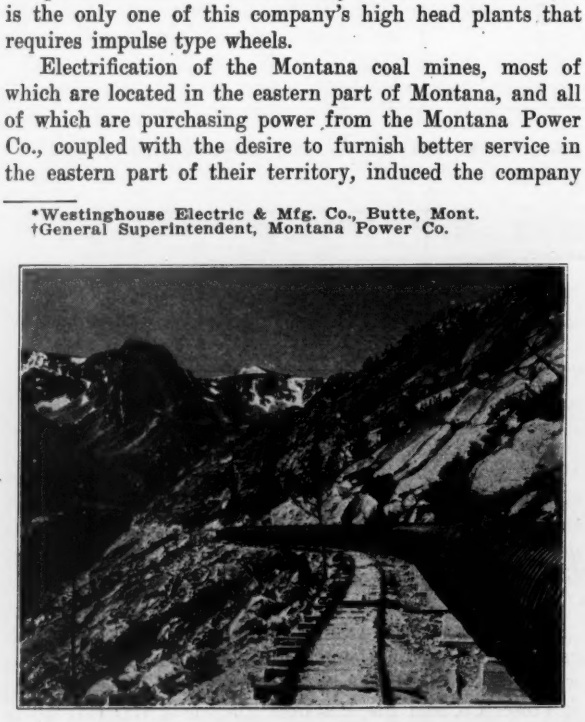


FIG. 1. A 12-FT. BENCH ON THE MOUNTAIN SIDE CARRIES THE WOOD STAVE PIPE LINE AND THE NARROW GAGE SERVICE TRACK

MYSTIC LAKE TO PROVIDE RESERVOIR OF 20,500 ACRE-FT.

After thorough investigations, extending over a period of years and covering all available sites in the eastern part of the state, Mystic Lake, a site located high up towards the summit of the Beartooth Mountains, and one of natural beauty, as shown in the headpiece, was chosen for this new development. This lake, from which the development takes its name, is located approximately 20 mi. northeast of Yellowstone National Park, and approximately 45 mi. from Columbus, Montana, the nearest railway point. It lies at an elevation of approximately 7700 ft. and is the largest of a chain of six lakes in the West Rosebud River. It is about 2¼ mi. long by ½ mi. wide with a surface area of nearly 347 acres. The present storage area to be utilized by the plant is 12,700 acre ft. which will be increased to 20,500 acre ft. within a short time by the construction of an arch dam across the present outlet, raising the elevation of the lake 20 ft.

The drainage area of the project is about 50 sq. mi. and within this area are the remaining lakes of the Mystic Lake chain, two of which can be dammed up at a reasonable cost to give considerable water storage. With the effective use of the storage available in the drainage area, the Mystic Lake Plant has been developed to utilize a maximum flow of 150 sec.-ft. The plant is designed to carry continuous full capacity load, leaving the regulation of the system to the larger plants operating in parallel.

Other principal plants of this system, with the exception of Thompson Falls, have been located on the Missouri River or its tributaries and operated as a chain of plants for which immense storage has been provided at the head waters of the river and passed through each succeeding plant, making an economically operated system, assured of steady reliable water supply. Due to the immense amount of storage that has been available in this system and the

reliable operation that could be secured, it has been unnecessary to maintain any steam reserve whatever, with the result that the Montana Power Co. today is the second largest power system depending solely upon hydro-electric plants.

Rugged Country Created Many Construction Problems

Because of the location of this plant, 45 mi. from the nearest railway, it was necessary to construct 15 mi. of private highway to connect with the present roads. This highway was constructed to the best standards, hard surfaced most of the way, at a cost of approximately $75,000 and represents a valuable addition in good roads to the section of the country where the plant is located.

Although the construction of the power plant itself was not a difficult engineering problem, the tapping of the lake with the pressure tunnel, and the construction of the steel and wood pipe lines presented a difficult task, in that they had to be completed at the same time as the rest of the project. Greater hazards and difficulties, however, were encountered in the operations of grading for the steel penstock. To carry out this construction, a 50-hp. gasoline hoist was first taken in sections, by means of pack horses and block and tackle, to a point close to the present surge tank, at the upper end of the steel pen stock. This small hoist was used in the construction of a narrow gage incline railway from the power house site up the side of the mountain along the route of the pen stock. After the construction of the railroad, an electric hoist was permanently installed at the top of the grade and served by a power line, which had in the meantime been brought in to take care of the output of Mystic Lake, from Red Lodge, a point on the Montana Power system.

From the top of the incline, 9000 ft. of bench 12 ft. wide, as shown in Fig. 1, for the accommodation of the 56-in. wood stave pipe line and the construction railroad, was graded to the lower end of the pressure tunnel. As the grading progressed a 3-ft. gage railway was installed to move materials for the wood stave pipe line and also supplies for the tunnel work, which had up to this time been carried by pack horses.

The feat accomplished in the tapping of the lake 48 ft. below the surface is of special importance because it is one

FIG. 3. SWITCHBOARD AND CONTROLS ARE IN A SEPARATE ROOM BEHIND THE UNITS, WITH TRANSFORMERS ON EITHER SIDE

of the few times that a project such as this has been accomplished. The pressure tunnel was carried through granite, said by the contractors doing the work to be the hardest ever encountered. Due to the nature of the formation no timbering whatever was necessary, until a large vertical fault was encountered at 930 ft, which brought a flow of 15 cu. ft. of water per second into the workings. This difficulty was met by dropping back into the main tunnel, a distance of 65 ft., and driving off to the left at an angle of 40 deg. as to cross the fault at almost right angles, so that the original tunnel would relieve pressure to such an extent as to make this second crossing possible. This plan was successful and the pilot tunnel was driven to the point where the original plans called for the sinking of an operating shaft for the installation of head gate control. It was then possible to drive ahead with the original tunnel which was successfully carried out to a point where the roof of the tunnel was about 11 ft. and the bottom approximately 18 to 20 ft. from the lake. Driving beyond this point was considered impractical and unsafe due to the increasingly large volume of water being encountered.

It was estimated that 700 yd. of material still remained

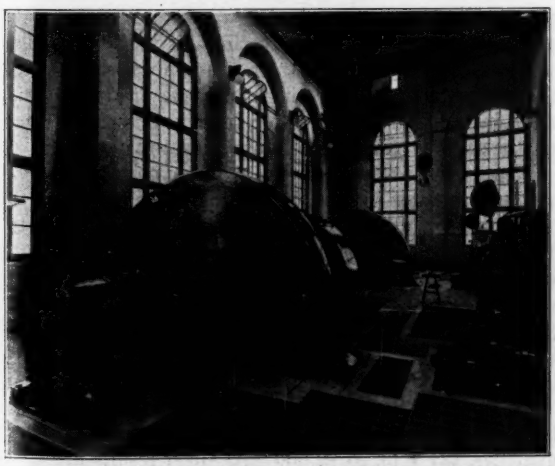


FIG. 2. GENERATORS ARE DRIVEN BY PELTON WHEELS WITH OIL-OPERATED GOVERNORS

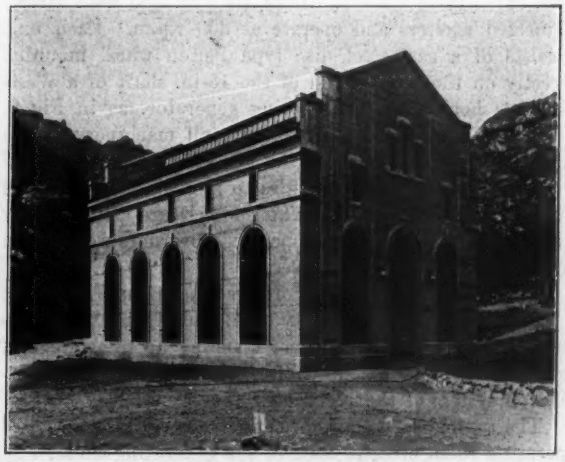


FIG. 4. SIMPLE BUT ATTRACTIVE DESIGN CHARACTERIZES POWER HOUSE DESIGN BOTH INSIDE AND OUT

to be moved by the final shot for the opening, a total of 6500 lb. of explosive being used. To make the shot certain three firing systems were installed: one series electric, the second parallel electric, and the third Cordeaux. To back up the shot a tight bulk head was installed near the tunnel portal and after loading, the tunnel was allowed to fill up completely with water.

As the lake was opened during low water flow in December it was found possible to bulk-head the water from the workings so that head works could be completed. To prevent the future filling up of the open cut by falling rocks a concrete culvert was installed and covered over with 4 ft. of loose rock. Due to the shattered ground it was necessary to concrete line the last 85 ft. of tunnel from the operating shaft.

Wood Stave Pipe Connects Tunnel With Steel Pressure Pipe

Connection at the lower end of the tunnel to the 56-in. Continental wood stave pipe was made by means of a steel bend, concreted into the tunnel opening and grouted to the tunnel wall, with neat cement forced in under 80 lb. pressure.

The 9000 ft. of wood stave pipe laid on the flow line grade was erected on pre-cast concrete foundations with 10-ft. spacings, as shown in Fig. 1. The lower end of the wood pipe connects to a steel T, the lower end of which is connected to a 48-in. electrically operated Pelton butterfly valve; the T connects to a Johnson Surge Tank, designed to take care of fluctuations in both the flow line and pressure pipes.

The steel pressure line is about 2750 ft. long, of Kellogg manufacture, designed for 650 lb. pressure at the lower end. This line is erected on concrete footings arranged with roller bearings and spaced 20 ft. apart. Ten expansion joints are provided for longitudinal movement with eleven permanent concrete anchor piers for holding the pipe line with expansion joints.

Power House Contains Two 6252-Kv.a. Units

The power house is of simple reinforced concrete, as shown in Fig. 4, with all operating equipment and control mounted on one operating floor and designed for operation by one attendant per shift.

Two 3-phase generating units are installed, each of 6250 kv.a. capacity at 6600 v. They are provided with direct-connected exciters and operate at 300 r.p.m. Each unit consists of a cast steel disc type Pelton wheel mounted directly on the flanged end of the 18-in. shaft of a Westinghouse horizontal, two bearing generator, as in Fig 2. Because of the necessity of hauling all machinery to the power house site in trucks, the generators were arranged with rotors split at right angles to the shaft, to be bolted together during erection. Water wheels are controlled by standard Pelton 150-lb., oil-operated governors working on double regulating needle valves.

The Westinghouse transformers, shown in Fig. 3, are 3 phase of 6000 kv.a. capacity each, and of shell type construction, with one transformer stepping up the voltage of each generator to 55,000 v. for connection to the transmission system of the Montana Power Co.

The switchboard equipment is mounted in an enclosed operating room directly back of the generating units, Fig. 3. The entire layout of the plant is simple throughout, at the same time maintaining high engineering standards.

The Charles T. Main Engineering Co. of Boston, Mass., were the consulting engineers in charge of the work with R. A. Moncrieff as resident engineer. The engineering department of the Montana Power Co. was directly in charge of all construction on the project.

Suggestions for Improving Ice Plant Operation

AT A RECENT meeting of New York Chapter No. 2 of the N. A. P. R. E., held in New York City, a discussion by the members present of several phases of refrigerating plant operation brought forth many interesting data and some valuable suggestions as to practical methods. Several of these suggestions are given below in the hope that they will prove of use to other refrigerating engineers.

J. Berndt commented on the record made this summer at the plant of the Fulton Ice Co. There are 2160 cans of 300-lb. capacity each, or 13.5 cans per tons for 160 t., yet, with the machines, condensers and cold water provided for, the average output during the past summer months was 200 t. per day. This means 10.8 cans per ton, and a freezing time of 39 hr. Brine temperatures were 12 to 13 deg., and evaporator pressure was 19 lb., corresponding to 4.5-deg. gas, equivalent to a temperature difference between brine and ammonia vapor of 8 deg. F. In the forecooler the can water is cooled to 39 deg. with vapor at 26 deg. (40 lb. gage). The ice is clear. The total power consumption per ton of ice ranges from 38 to 43 kw-hr.

Mr. Berndt emphasized the importance and economy of a constant clockwise rate of pulling. In his plant there are three 8-hr. shifts, and no can is allowed to remain in the tank to absorb more than its minimum quota of refrigeration. Mr. Berndt believes also in having plenty of brine space in freezing tanks, using coils set with 15½-in. centers rather than 14½-in. centers as is often the case with several feet of extra length at the ends of the tank "to give the brine a chance to move," as he put it. Other conditions being equal, he found that such a tank would produce 90 t. of ice a day as against 75 t. with the usual design that does not provide this extra space.

Charles H. Herter presented some useful operating hints, of which the following are typical. To prevent bearings from heating, more or less automobile spring lubricant can be added to bearing oil. This fluid can be used in compressor cylinders also, because it remains liquid at —50 deg. F. but as it costs about 15 times as much per gallon as other compressor oil, it is attractive only in emergencies and for household refrigerating machines. It also comes in handy in many other ways for loosening seized, frozen, rusty or squeaky parts, tight hinge pins, nuts and the like.

Where high pressure air at 15 lb. or more is used for aerating the water in cans, yellow lubricating oil from the air compressor may appear at times in the core of the block. As this is unsightly, it is suggested that clear white mineral oil be used, fed as sparingly as possible by means of a mechanical lubricator. Satisfactory ammonia compressor oil can be had at 25 to 30 cents per gallon, Mr. Herter said. He feels that it is unnecessary for ice plants to pay double this price.

To improve further the clarity of raw water can or plate ice, alum can be added to the freezing water in small quantities, say 1 lb. to 15,000 gal. Good results are being obtained with lump sulphate of alumina, iron free, obtained in 360-lb. drums. To save money on fire extinguishing

fluid, carbon tetrachloride can be obtained from chemical supply houses. Five gallons of this weigh about 65 lb. and cost about 15 cents per lb.

System Load Curve Affects Motor-Driven Ice Plants

COMPARISON OF ICE PLANT PEAK LOAD WITH CENTRAL STATION LOAD CURVE DETERMINES TYPE OF POWER CONTRACT AND INFLUENCES PLANT DESIGN. BY HARRY L. SEMANS

REFRIGERATING ENGINEERS who must decide between purchasing electric power or generating their own electricity should give careful study to the provisions of the contract offered by the central station. These provisions depend on many factors and the following brief discussion of the considerations on which the power company bases its contract may help the engineer in understanding the viewpoint of the latter.

Many electric power companies, particularly those whose loads consist largely of lighting, have annual peak loads that are similar to the annual peak loads in the ice manufacturing business but that occur at a different time in the year. Companies that have an extreme winter peak load and a decided summer hollow in the annual load curve are anxious to find something which will tend to straighten this curve. In casting about for such business, it was discovered that the extreme high peak of the ice manufacturing business coincided almost identically with the greatest depression in their own business and tapered either way from their own peak in about the same proportion.

Existing power contracts were made up on the assumption that the customer would use about the same amount of power during each month and service charges were made on the same basis. The ice plant offered a heavy, continuous load with a high demand during the summer months and a light load with small demand during the winter months. It was seen by such companies that this load would be of sufficient advantage to them, in permitting them to operate at higher efficiency, to enable them to waive the winter service charge to some extent. Off-peak contracts or off-peak riders, therefore, were devised for existing forms to cover the situation.

Not all of the power companies were in this position, however, those having a load in which power predominated did not have the extreme peaks and dips in the annual load curve shown by those having little power load but a heavy lighting load. In such cases there was no advantage to the power company in taking on the ice plant load, from the standpoint of straightening the load curve, consequently it became just that much added to the power load and was treated accordingly.

Still other power companies showed no dip in the annual load curve during the summer months and in some cases a slight summer peak. In such cases the ice plant load was undesirable unless there was a surplus of equipment in the power plant. In either event the ice plant load meant no saving in operation and nothing but the usual form of power contract could be offered.

These are some of the reasons for the wide variation in rates offered to ice plants by different power companies. The inducement offered depends upon the desirability of the load to the individual power company.

TYPE OF CONTRACT INFLUENCES DESIGN OF PLANT

Before reaching a decision as to the kind of power to be used in an ice plant it would be well to determine which of the above classes includes the power company from whom service must be secured. The engineer should make a thorough study of the contract offered and test it out by applying it to conditions existing in some other motor driven plant of about the same size as the one contemplated. After these things have been carefully checked and it is determined that motor drive is to be used, the plant should be designed to take full advantage of the power contract.

In some cases it would be better to install one or two large units; in others several smaller units would be an advantage. Sometimes it is better to install an excess of condenser surface, can surface and coil surface, while in others the saving would not pay the overhead on the added investment. The power contract would also determine to some extent whether to build a large storage house or to add enough ice-making equipment to the plant to meet the peak demands of the summer months.

When the power contract is made it should be thoroughly studied by the plant engineer and the plant manager and the operation laid out by them from month to month. Both should consult freely with officials of the power company serving them, to make sure that the contract is understood in every respect. After operation conditions for a given period have been determined, they should be adhered to as closely as possible, in order to create the best load factor obtainable. Selection of motors will be influenced to some extent by the conditions contained in the power contract. The amount of consideration given to power factor and synchronous motors means much to the ice plant owner and the power company.

Thorough knowledge of the provisions of the power contract is essential to the proper design and operation of a motor-driven ice making plant.

NEED OF MORE and better facts in regard to output of products, supply and demand, and market conditions as a guide in business management is emphasized in a bulletin recently issued by the Department of Manufacture of the Chamber of Commerce of the United States. Gathering, compiling and making available to the public and to the Government current figures which will give a picture of what is going on in industry is a valuable service that trade associations can render so that producer, distributor and consumer may act intelligently. This will help to avoid peaks and valleys in trade, unemployment and market demoralization.

When gathered, these statistics should be so presented that the ordinary man on the street can understand and use them. Too often the form of presentation has been arranged to suit the statistician and has been too complicated for use by the business man. Letters from users of data now available, such as for some metals, brick, woods, paper boxes and motor accessories, bear testimony to the value of these statistics in directing the operation of factories and judging of markets. Unquestionably other industries can get similar help if they will co-operate in getting and properly presenting trade data.

DON'T EXPECT to retain the superheat in your steam unless you properly insulate your steam lines.

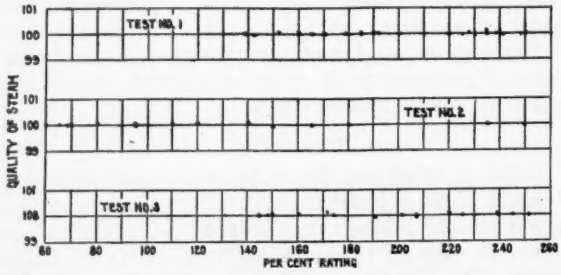
Efficiency Characteristic of Baffle Type Steam Purifier

By Grant D. Bradshaw*

IN THE article on "Causes of Priming" published in Power Plant Engineering January 1, 1926, page 59, a test is shown of the results obtained with a centrifugal type separator within the steam drum of a boiler showing results varying from 4½ per cent moisture in the steam leaving the boiler to ½ of 1 per cent moisture.

Moisture in the steam of 4½ per cent on a rating of 118 per cent would, of course, hardly be permissible in modern practice. Even the ½ of 1 per cent shown, which is the minimum amount of water left in the steam on this test, would carry so much impurities through the superheater into the steam line that very little can be said for the efficiency shown in this test in any way whatever. Boilers with even the old-fashioned dry-pipe have been known to give results of only ½ of 1 per cent moisture over quite a wide range. In a 1000 hp. boiler running at 200 per cent of rating with a concentration of 200 grains per gallon, ½ of 1 per cent moisture in the steam will put through the steam system over one pound of impurities every hour, or over one-third of a ton per month.

The statement is made that as the rating increases moisture content decreases, as is to be expected with the centrifugal type of separator which depends upon velocity for its efficiency. The statement also is made that the exact reverse is true of the baffle type purifier which depends upon low velocities of steam for best results. This is incorrect, however, for while the baffle type purifier does depend on low velocities for results, the characteristic curve is a horizontal straight line over the entire range of boiler output at the 100 per cent steam quality point, or point of zero moisture, as can be seen from the following tests.



QUALITY OF STEAM DURING TESTS OF BAFFLE TYPE PURIFIERS

Test No. 1 shows calorimeter determination made by the engineers of a large steam company in the Pittsburgh District on a 526-hp. boiler operating at ratings all the way from 138 per cent up to 250 per cent. The points form an absolutely straight horizontal line on the 100 per cent mark within, of course, the limits of error of observation and of calorimeter, clear to the limit of the boiler operation.

Test No. 2 is a test made by another of the large steel companies on an 829-hp. boiler at ratings varying from 60 per cent up to 250 per cent. This test shows, as you will note, an average of zero moisture throughout the entire range of operation. There is no sign of a falling off in steam quality at the higher boiler ratings.

Test No. 3 comprises observations taken by engineers of a large manufacturing concern on a 2250-hp. boiler, ratings varying all the way from 124 to 252 per cent. This shows the same characteristic curve—the horizontal straight line at the 100 per cent steam quality point.

In addition these tests all show that the results are practically perfect from one end of the range of boiler operation to the other.

This horizontal efficiency curve is one of the vital features in the operation of steam purifiers or separators located within the boiler drum. In order to obtain clean, dry steam at all times, and particularly in order to avoid deposits in steam line, turbines, traps, steam strainers, etc., it is essential to have an apparatus which has practically perfect separating efficiency from zero load up to the maximum rating that the boiler can deliver. This is the particular function of the baffle type purifier and is the reason for its remarkable success.

RESULTS OF TESTS ON QUALITY OF STEAM WITH BAFFLE TYPE PURIFIERS

Test No. 1				Test No. 2		Test No. 3	
Per Cent Rating	Quality	Per Cent Rating	Quality	Per Cent Rating	Quality	Per Cent Rating	Quality
138	100.00	220	100.00	60	100.00	144	100.00
142	99.95	225	99.95	65	100.00	148	100.05
152	100.05	225	99.95	68	100.00	150	100.00
150	100.00	228	100.05	70	100.00	150	100.05
160	100.05	230	99.95	70	100.05	161	100.05
160	100.00	230	100.00	80	100.11	172	100.15
165	100.00	235	100.05	95	100.00	174	100.00
170	100.00	235	100.00	95	100.05	186	99.95
170	100.05	235	100.16	110	100.05	202	100.00
178	100.05	238	100.00	120	100.05	208	99.95
180	100.00	240	100.00	140	100.16	208	100.00
185	100.05	240	100.05	150	99.95	220	100.05
185	100.00	240	100.00	165	99.95	226	100.00
190	100.00	240	100.11	180	100.00	230	100.00
190	100.05	242	99.95	235	100.00	239	100.00
192	100.00	242	99.95	250	99.95	239	100.05
196	100.00	248	99.95			245	100.00
200	100.00	250	99.95			252	100.00
200	100.00	250	100.05				
200	100.00						

Purifiers of this type, using six rows of staggered, gutter type baffles, and draining away the boiler water removed from the steam to a point outside the boiler, by means of a trap, are now in use in boilers aggregating more than 2,000,000 b.hp.

In all of this large list of plants the operating force is well informed as to the difference in plant maintenance between the use of steam that has been thoroughly cleaned and steam carrying ½ of 1 per cent or larger amounts of boiler water, with its man tons per year of dissolved and suspended impurities.

*Andrews-Bradshaw Co., Pittsburgh, Pa.

The Pacific Gas & Electric Co., 245 Market Street, San Francisco, Calif., is arranging an appropriation of about $25,000,000 for extensions and improvements in generating and distributing facilities during 1926. Additional construction will be carried out at the No. 4 hydroelectric generating plant on the Pit River, including power dam and intake, with total cost estimated at $15,000,000; the Fordyce power dam will be increased in height and improved at a cost of $400,000; the Drum canal and Spaulding tunnel constructed at a cost of $250,000; transmission lines constructed from Manteca to Salinas at a cost of $598,000; and extensions and betterments made in lines and facilities at San Jose and vicinity at a cost of $750,000. New substations will be constructed as follows: Redwood City, $175,000; Manteca, $200,000; Salinas, $130,000; Hayward, $190,000, and San Mateo, $165,000.

Vacuum System Gives Steady Water Flow

In a large industrial plant where I am employed we have an hourly demand for several thousand gallons of water. Until recently, not only was there considerable fluctuation in pressure but the pump would become air-bound and lose the water, sometimes 8 or 10 times a day. This is shown graphically in Fig. 1. Note the number of times the pressure dropped to zero and suction was lost.

To remedy the trouble a vacuum system was connected to the suction side of the pump as shown in Fig. 2. Water from the Wabash River is drawn through a 16 in. line, 1200 ft. long. This is connected to a tank, 4 ft. by 6 ft. in horizontal cross section and 10 ft. high. In the center of the tank is a solid partition 4 ft. high and above this is a ¼-in. mesh screen, which may be removed for cleaning, through the top of the tank.

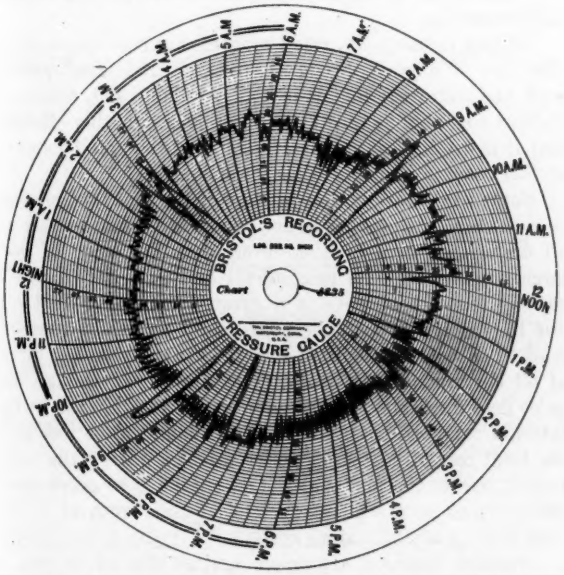


FIG. 1. BEFORE INSTALLING THE VACUUM SYSTEM THE WATER PRESSURE CHART LOOKED LIKE THIS

Vacuum of 20 in. mercury is maintained in the tank by means of a centrifugal vacuum pump, driven with a 10-hp. motor at 650 r.p.m. The line connecting the vacuum pump to the tank is provided with the U-shaped riser extending 24 ft. above the tank to prevent water being drawn into the vacuum pump when the river is high.

Just above the pump and connecting to the vacuum line is a ½-in. line from the city water service. The valve on this line is partly open at all times. If, for any reason, the vacuum pump stops, the check valve closes and the water seals the line to the vacuum tank. This prevents the main water supply pump from losing suction and the water emptying to the river. Normally the amount of water from this ½-in. line, drawn through the vacuum pump is so small that it has no effect on the operation.

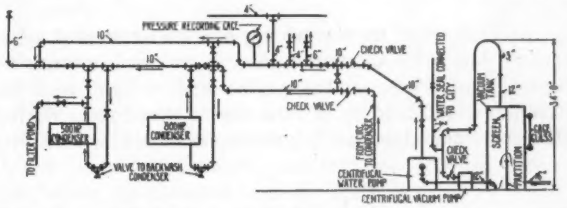


FIG. 2. ELEVATION OF PLANT WATER SUPPLY LINES SHOWING VACUUM SYSTEM INSTALLED ON SUCTION SIDE OF WATER PUMP

Results of this vacuum system have been so satisfactory that the watch engineers have named it "Little Eureka." Compare the fluctuating pressure shown in Fig. 1 with that shown in Fig. 3. The small hooks shown at a few points were due to a fluctuation in voltage on the motor driving the water pump. Since providing the vacuum system, the pumps run continuously from Monday morning to the following Sunday morning without a single stop.

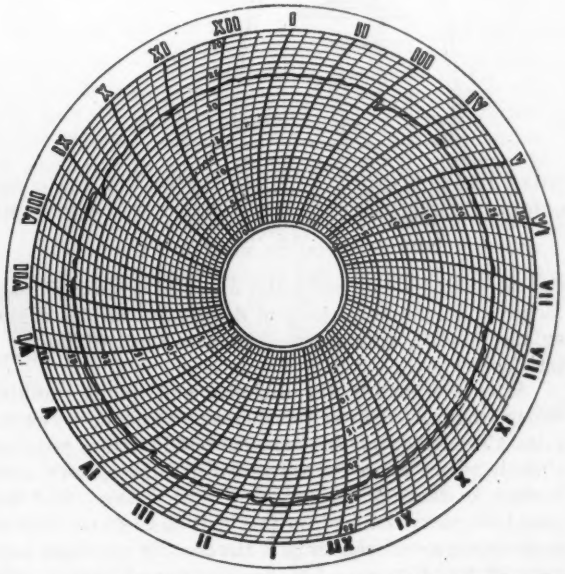


FIG. 3. THIS CHART SHOWS THE STEADY WATER PRESSURE MAINTAINED AFTER THE VACUUM SYSTEM WAS INSTALLED

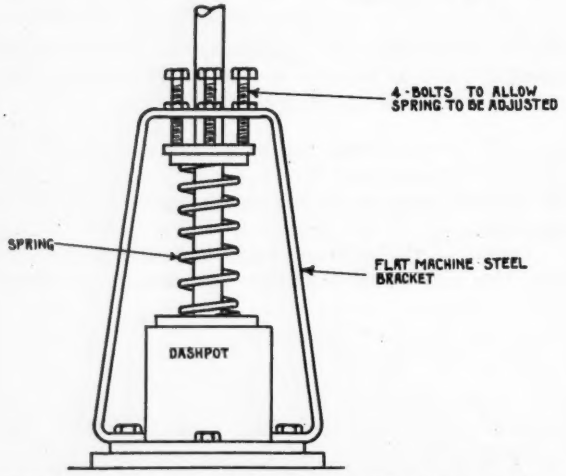
Wabash, Ind. I. N. Williams.

Dashpot Assisted by Spring

At times when the load was light, our Corliss double eccentric engine would hold up its dashpots, causing the steam ports to stand open slightly. Double eccentric engines have only a slight lap when the dashpot is down, this being necessary in order to get the long range cutoff. With 125 lb. steam pressure and a light load, it requires only a slight opening of the ports to cause excessive speed.

This defect, however, could be remedied by opening the air valves wider so as to decrease the cushioning, nevertheless it was a nuisance. Finally it was decided to have the cylinder and ports rebored and to purchase new steam and exhaust valves. Accordingly, we hired a regular engine repairing concern to give the engine a general overhauling.

At first, when we started up, everything seemed satisfactory but soon we found that if we used a pressure higher than 80 lb. on the engine with a light load the dashpots would hold up and the engine would race. Giving the repair men due credit, however, it should be said that



WHEN THE DASHPOT ON A CORLISS ENGINE WOULD NOT ACT QUICKLY, THE ENGINEER ATTACHED THIS ADJUSTABLE SPRING

the valves were set correctly and indicator cards were satisfactory. So the only thing to do was to run the engine on the throttle, although we had paid them $1200 for a satisfactory job.

After overhauling the dashpots and finding nothing wrong, they called in more experts but with no better results. Then they advised me to use 80 lb. steam pressure, since it would cause the valves to lift higher, draw more vacuum in the dashpot and slow down better. But this would not carry the load, so they quit and left me with an engine that would run away if the throttle was open halfway.

Shortly afterward, I found the engine running at about 150 r.p.m. instead of the normal 90 r.p.m. The governor was trying to hold it, being way up, but the dashpots were bouncing and opening the valves. I shut down the engine and suggested to the superintendent that we provide the dashpot rod with a spring as shown in the accompanying sketch. This spring is made of ¼-in. round steel and the coil is 2½-in. diameter and 12 in. long when not compressed. At the top are four ⅜ by 6-in. set-screws for adjusting the tension which I have been able to decrease considerably as the valves get smoother. The framework holding the screws is made of ½ by 3-in. flat machine steel.

This device has been operating about 4 yr. and is still giving excellent results. The engine has been run with pressures as high as 148 lb. without overspeeding.

Malden, Mass. Sam Bow.

Oil Engines Often Solve Power Problems

For many years alert engineers have been seeking a prime mover more economical than the steam engine which, although cheap in initial cost, is not always economical in daily operation.

Many of the older steam power plants now in use are proving to be as costly as they were inefficient in the first place. When first installed, they were satisfactorily economical but were not efficient. Today they are neither economical nor efficient. The cost of fuel has gone up so much that in many of our modern plants efficiency could be greatly increased by improved methods in the boiler room and in the engine room if more power is needed, a great saving could be effected by leaving the old engine in place and installing a low pressure turbine to operate on the exhaust from the present engine. Such things are possible and should be considered.

A large number of plant owners have solved the problem satisfactorily by installing an electric motor and buying power from central stations. Others have installed oil engines and are now getting good results where formerly they had made practically no profit with the old steam plant operation.

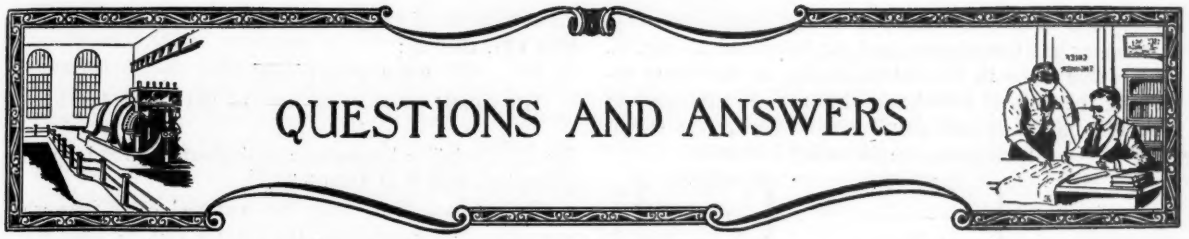
During recent years, rapid progress has been made, with this type of engine. So much research and development work has been done that it is highly reliable and, although the first cost may be considered high, it is so highly efficient that it is actually economical because of the small amount of fuel consumption per horsepower hour.

Some people argue that because of the fact that oil fuel is so unstable in price it is not good business to install an oil engine. It is a fact, however, that the price of coal largely determines the price of oil and there is a definite co-relation. When there is a great demand for fuel oil, due to scarcity of coal, the price of oil naturally goes up. And when coal is plentiful and its price drops, the price of oil correspondingly drops. Therefore, even though the price does fluctuate, the ultimate cost of fuel for use in the internal combustion engine is almost bound to be less than the total cost of coal fired under a boiler during the same period, due to the fact that the oil engine is so much more efficient and so much less fuel is required even of a fuel that may be slightly more costly.

Another common argument against the oil engine is that it is more difficult to operate than the steam power plant. This is no longer true—at least it is less serious than it once was. In fact, it is claimed by manufacturers of this type of engine that it does not require any more skilled attention than a steam plant. There is less danger with an oil engine since there is no boiler to explode.

When installing an oil engine, take special care with the cooling system. Use water for cooling that will not deposit scale in the jackets. Be sure that the water circulation is perfectly free, positive and continuous. Also, be certain that the engine is always well lubricated externally as well as internally. All of these points must be observed if high efficiency is to be maintained.

Newark, N. J. W. F. Schaphorst.



Study These Indicator Diagrams

READERS are asked to comment on the accompanying indicator diagrams, telling how improvements may be made. How can more power be obtained from the engine

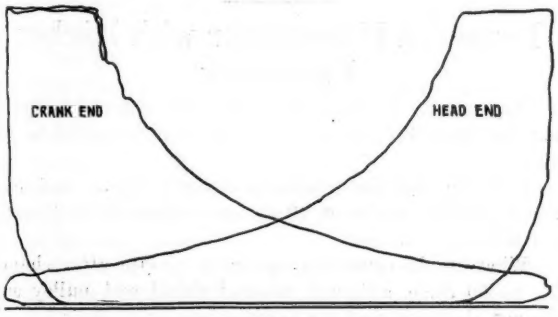


FIG. 1

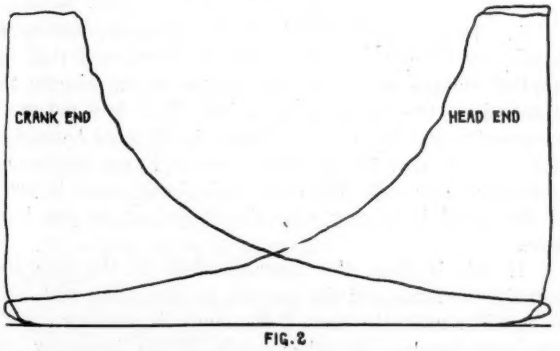


FIG. 2

THESE DIAGRAMS WERE TAKEN ON A SINGLE ECCENTRIC CORLISS ENGINE, 15 IN. BY 30 IN., RUNNING AT 72 R.P.M. STEAM PRESSURE FOR FIG. 1 WAS 120 LB. GAGE

from which diagram No. 1 was taken? The present load causes the engine to carry over, that is, fail to release.

T. L. K.

Chimney Load Determined by Variable Factors

AT present we have 1100 rated boiler horsepower but are planning the purchase of 3 more 800-hp. boilers. Only two of these, however, will be operating at a time so that the total operating load will be 2700 boiler hp.

We are now burning oil with about 12.7 per cent CO_2, using a chimney 96 in. diameter by 208 ft. high. With the proposed load of 2700 rated boiler hp., what is the maximum load this chimney will handle with either oil firing, stokers, or a pulverized coal system? A. C. D.

A. In order to figure the per cent of excess air with each method of firing, we must have an analysis of the fuel and also the amount of CO_2 being obtained. Since no fuel analyses have been given, we are assuming the following:

C	84.0	79.86
H	12.7	5.02
O	1.2	4.27
N	1.7	1.86
S	0.4	1.18
Ash	....	7.81
B.t.u.	18,700	14,000

With the foregoing analyses, the maximum theoretical CO_2 for oil is 15.4 per cent and for coal, 18.4 per cent. These values are obtained from the formula:

$$(1) \qquad M = \frac{20.9}{1 + \frac{2.38\ (H - O/8)}{C}}$$

where, M = maximum CO_2; H, O and C are the per cents respectively given by an ultimate analysis. Per cent excess air may be figured by the formula:

$$\text{Excess air} = \frac{\text{Max. } CO_2 - \text{actual } CO_2}{\text{Actual } CO_2}$$

At present, with oil firing you are using about 20 per cent excess air. When firing coal with stokers, you probably will obtain an average of 13 per cent CO_2 which will give you 40 per cent excess air. When burning pulverized coal, the average operating CO_2 hardly will exceed 14 per cent, anything higher being detrimental to brick work. This corresponds to about 30 per cent excess air.

In order to compare the actual velocity with the theoretical, it is necessary to know or assume the temperatures of the chimney gas and outside air, the loss of draft due to velocity, and the density of the chimney gas.

Density of the chimney gas may be calculated by the following equation:

$$(2) \qquad W = 0.123\ CO_2 + 0.089\ O_2 + 0.078\ N_2$$

where, W = weight in pounds per cu. ft. at 32 deg., and CO_2, O_2 and N_2 are the respective per cents of these gases in the chimney gas. This weight may be corrected to outside air temperature by multiplying by the ratio of absolute temperature at 32 deg. to the absolute temperature of the outside air. For exact work, changes in atmospheric conditions should be considered, but ordinarily this factor may be neglected.

For stokers, $W = (0.123 \times 0.13) + (0.089 \times 0.054) + (0.078 \times 0.816) = 0.0844$ lb. For oil, $W = (0.123 \times 0.127) + (0.089 \times 0.027) + (0.078 \times 0.846) = 0.084$ lb. for pulverized coal, $W = (0.123 \times 0.14) + (0.089 \times 0.044) + (0.078 \times 0.816) = 0.0847$ lb.

It is impossible to give any definite values for chimney gas temperatures. These will depend not only on the amount of excess air but also on the elevation of chimney gas temperature above that of the saturated steam in the

boiler. For a working example, we can assume 600 deg. F. chimney gas temperature and outside air at 32 deg. F.

We now come to the determination of the factor expressing the ratio of actual velocity to the theoretical. In a recently published book on "Draft and Capacity of Chimneys," J. G. Mingle gives the following formula:

$$(3)\quad R = 0.0268\left[\sqrt{\frac{PT_c\,d}{W}} \div \sqrt{H\left(\frac{r\,T_c}{T_o} - 1\right)}\right]$$

where, R = ratio of actual to theoretical velocity; P = atmospheric pressure, lb. per sq. in.; T_c = absolute chimney gas temperature; d = loss of draft due to velocity friction, assumed 0.10 in. of water; W = weight of 1 cu. ft. of chimney gas at outside air temperature; H = chimney height in feet; r = ratio of absolute temperature at 32 deg. to absolute temperature of outside air; T_o = temperature of outside air. Substituting in our problem, we have for stokers:

$$R = 2.268 \times \left[\sqrt{\frac{14.7\times1060\times0.10}{0.0844}} \div \sqrt{208\left(\frac{1.0\times1020}{492} - 1\right)}\right] = 0.244$$

In like manner, R = 0.245 for oil firing; and for pulverized coal, R = 0.243.

To obtain the "horsepower equivalent" of a chimney for a circular section based on the diameter, Mr. Mingle gives the following formula:

$$(4)\quad \text{Hp.} = 864\,\frac{R\,D^2\sqrt{H}}{W_1}$$

where, R = ratio of actual to theoretical velocity; D = diameter in feet; H = height in feet; W_1 = pounds of gas per boiler hp. per hr.

For each of the methods of firing the value of W_1 is found in two steps. First, by multiplying the heat value of the fuel by the efficiency and then dividing this result into 33,500 (B.t.u. equivalent of a boiler horsepower) we get the number of pounds of coal per boiler horsepower per hour. Next, we must find the number of pounds of gas per pound of fuel.

Experiments have shown that for each 10,000 B.t.u. in a fuel, approximately 7.65 lb. air are required for theoretical complete combustion. Multiplying this figure by the ratio of the heat value of the fuel to 10,000 B.t.u., we get the number of pounds of air theoretically required per pound of fuel. Then multiplying by 100 per cent plus the per cent of excess air, we get the actual approximate pounds of air per pound of fuel. Adding 1 lb. to the latter figure, we get the actual pounds of gas per lb. of fuel, and then, multiplying the weight of fuel per boiler horsepower per hour by the pounds of gas per pound of fuel, we arrive at the value of W_1.

For stokers, the weight of gas per pound of coal is: $\frac{14{,}000}{10{,}000} \times 7.65 \times 1.4 + 1.0 = 16.0$ lb. gas. The weight of gas per pound of fuel, for oil is 18.2 lb.; for pulverized coal it is 14.9 lb. For stokers, we have 3.19 lb. coal per boiler horsepower per hour; for oil firing, 2.24 lb.; for pulverized coal, 2.91 lb. Values of W_1 for each method of firing are:

$W_1 = 3.19 \times 16.0 = 51.1$ lb. for stokers
$= 2.24 \times 18.2 = 40.8$ for oil
$= 2.91 \times 14.9 = 43.5$ lb. for pulverized coal

Final solution of the problem, substituting values in equation (4), then is:

$$\text{Hp.} = 864\,\frac{0.244 \times 64\sqrt{208}}{51.1} = 3810 \text{ b.hp. for stokers;}$$

for oil, the boiler horsepower equivalent is 4800 b.hp.; for pulverized coal it is 4460 b.hp.

This means that under the assumed conditions when operating 2700 rated b.hp., the average load for each boiler will be 141 per cent of rating with stokers; 178 per cent with oil firing; and 165 per cent of rating with pulverized coal. In actual operation, with these loads, the flue gas temperature will vary with the load and ordinarily will not reach 600 deg.

Increased Horsepower with Higher Frequency

WHAT IS the effect on the horsepower if a 10-hp. motor running at 800 r.p.m. at 40 cycles is reconnected to 60 cycles?

How do the characteristics (power factor and efficiency) of the motor at 40 cycles compare with 60-cycle operation?

What would cause the motor to vibrate after changing to 60 cycle, although the end shield and pulley end are not disturbed and the bearings are satisfactory?

J. E. L.

A. In reconnecting this 10-hp., 40-cycle, 800-r.p.m. motor for 60 cycles, 1200 r.p.m., it is assumed that the applied voltage on the motor will be varied exactly the same way as the frequency is varied. This does not mean necessarily that the voltage of the circuit need be varied, for the coils may be reconnected so as to get the proper voltage on each coil. But some such change must be made if the speed is to vary with the frequency, as you indicate.

If this is done, the magnetic field in the iron will remain the same and the current in the stator and rotor coils will remain the same if the motor is working against the same torque. In other words, if the frequency and voltage are varied together, the motor will develop the same torque at all times and have flowing in it the same current. If the torque remains the same, the amount of horsepower developed will vary directly as the applied frequency. In your case, therefore, where the frequency is changed from 40 cycles to 60 cycles, the horsepower will be $\frac{60}{40} \times 10 = 15$ hp.

With reference to your second question, the power factor and efficiency will not be altered materially by the change in frequency and speed. The density of the magnetic field in the iron and the current in the coils remain the same, as stated above. Consequently, the efficiency will not be affected. As a matter of fact, because of the higher speed on 60 cycles, the ventilation may be bettered somewhat and the motor running cooler, may have a slightly higher efficiency than on the lower frequency.

In reconnecting a motor, the power factor is usually decreased by an increase in voltage or a decrease in frequency and vice versa, but the total change is small. Where both the voltage and frequency are increased, as is the case with your motor, there should be no change in power factor.

The vibration referred to in your third question may be due to mechanical unbalance of the rotor or improper distribution of the coils in the stator winding. But it is difficult to state definitely what the true cause of this vibration may be without knowing more about the nature of the vibration (whether it is of a magnetic nature or of a purely mechanical nature). It also might be due to increased windage, caused by the increase in speed.

Heating Water in an Open Heater

How many heat units or how many pounds of coal will be required to raise the temperature of 3500 gal. of water from 50 deg. to 180 deg. F. with live steam at 100 lb. gage pressure; also with exhaust steam at 5 lb. pressure? The water is to be heated in 20 min. W. S. H.

A. It is not clear whether the problem means that a given amount of water in a tank is to be heated by discharging steam directly into the tank or whether coils are to be used. We assume, however, that the steam is to be discharged into a tank or open type of feed-water heater and the water heated in this manner. We also assume that by "live" steam is meant dry saturated steam. We cannot give an exact answer in terms of the number of pounds of coal necessary to heat the water, since we do not know the kind of coal used in producing the steam nor at what efficiency the steam is generated.

If no loss to radiation is considered the number of pounds of steam necessary to heat 3500 gal. of water in one hour may be figured by the following formula:

$$W_1 = \frac{(W_2 - W_1)\ (t - t_o)}{(H - t + 32)}$$

Where W_1 = pounds of steam per hr.
W_2 = total amount of water heated per hour
H = total heat in 1 lb. of steam
t_o = initial water temperature
t = final water temperature

In this case
$W_2 = 3500 \times 8.33 = 29{,}200$ lb. water.
Where $H = 1189$ B.t.u.
$t_o = 50$ deg. F.
$t = 180$ deg. F.
Substituting we have

$$W_1 = \frac{(29{,}200 - W_1)\ 130}{1041} = 3240 \text{ lb. steam}$$

In this case W_1 is subtracted from W_2 in the equation, since W_2 is the total amount of water to be heated and, of course, includes the amount of condensate from the steam used to do the heating. Since your problem requires the water to be heated in 20 min., the amount of steam would be 3 times 3240 or 9720 lb.

Assuming that coal of 12,000 B.t.u. is burned at 70 per cent efficiency, the equivalent evaporation will be $(12{,}000 \times 0.70) \div 970.4 = 8.66$ lb. steam per lb. of coal. Then the amount of coal required to heat the water will be $9720 \div 8.66 = 112$ lb.

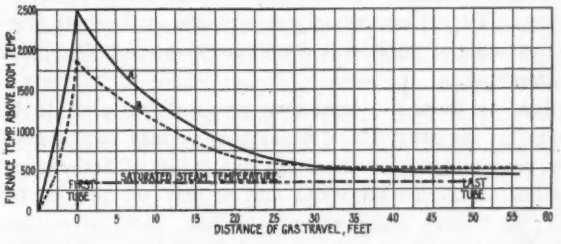
We cannot figure the amount of exhaust steam needed, since we do not know the quality of this steam. By this term we mean the number of heat units in the steam. Exhaust steam at 5 lb. pressure will not contain as many heat units as live steam of the same pressure, since a certain amount of heat has been extracted in doing work in the prime mover and also some has been lost to radiation.

Relation of CO_2 to Flue Gas Temperature

WHY SHOULD flue gas temperature be higher with high percentage excess air (low CO_2) than it is with low percentage excess air (high CO_2)? A. R.

A. Ordinarily when there is high CO_2 there is low excess air which naturally produces a high furnace temperature, yet with this condition the flue or uptake temperature is lower than it is when there is a greater excess air and the CO_2 and furnace temperature are lower.

At first this may be hard to understand, since the natural tendency is to think that if the gas is hotter before entering the tube bank, it should be hotter when it leaves. This, however, is not true in most cases. The very fact that the gas is hotter before it enters the tube bank means that there is a greater difference between the furnace temperature and that of the saturated steam in the tubes in the case of high CO_2 than there is with low CO_2. Greater temperature difference means a higher rate of heat transfer and more heat absorbed by the tubes with high CO_2 than with low.



THESE CURVES, A FOR LOW EXCESS AIR (HIGH CO_2) AND B FOR HIGH EXCESS AIR (LOW CO_2), SHOW THAT WITH A HIGHER FURNACE TEMPERATURE THERE IS A HIGHER RATE OF HEAT TRANSFER AND CONSEQUENTLY LOWER FLUE GAS TEMPERATURE

Heat absorption in either case is cumulative and it requires a certain appreciable amount of heating surface for the gas to pass over to give results. Even though there is a greater temperature difference with high CO_2, the heat absorbed by a few tubes will not lower the gas temperature enough to make the low excess air show lower flue temperature than high excess air. The gas must make at least two passes through the tubes before the effect of greater heat transfer with high CO_2 will begin to show results.

In most water tube boilers after the gas has passed over 25 to 30 ft. of heating surface the effect of the higher heat transfer becomes evident. In the accompanying figure, Curve A is for high CO_2, say 35 per cent excess air and B for low CO_2, 75 per cent excess air. The temperature gradient is steeper with A than with B and after the gas has traveled for about 50 ft. the curves cross each other, A having a lower flue temperature than B. The same combustion rate is assumed in each case.

It should be explained that the point where these curves cross depends on a number of variable conditions, but if given time enough they will always cross somewhere.

THE HOLYOKE (Mass.) Water Power Co. has petitioned the Legislature for authority to extend its plant out into the Connecticut River at Holyoke, to secure additional power to meet the existing demand.

EDITORIAL COMMENT

Calling in the Doctor

Although it has been said that this is an age of specialists, in many branches of science the specialist has not been given due recognition. In no field of endeavor is this better exemplified than in power plant engineering. The average engineer consults his physician on the slightest symptom of an ailment but usually thinks he can diagnose the troubles of any piece of power plant equipment himself, sometimes with dire results.

In most cases, engineers can and should repair their own engines, pumps, stokers and other similar machines but in the case of boiler water treatment, expert advice should be obtained. Boiler water treatment, as practiced today in a large number of power plants, is the most glaring example of guess-work found anywhere in power plant engineering.

Just as there are numerous prepared remedies to be found in the drug stores, which may or may not be good for your ailment, so there are a number of boiler compounds on the market which may or may not be good for your particular boiler water. Soda ash, (sodium carbonate), or as it is known to housewives, washing soda, is the basic ingredient of many of these compounds, whether in dry or liquid form. As the chemists express it, when dissolved in water, soda ash "hydrolizes," forming sodium hydroxide and CO_2 gas. Sodium hydroxide is a strong lye and is popularly known as caustic soda. Even the novice knows what this will do to a boiler unless handled under expert advice and direction.

Every power plant engineer having charge of steam boilers of any size or type should read the article by Dr. R. E. Hall on boiler water conditioning in this issue of Power Plant Engineering. In investigating boiler water troubles Dr. Hall has rendered power plant operators a valuable service.

Boiler water treatment involves an intimate knowledge of chemistry and always should be given careful study. It is hoped that as knowledge of this phase of power plant engineering becomes more wide-spread, power plant operators will be considerate of their boilers as they are of their own bodies.

Engineers' Contribution to Conservation

To the men associated with the power plant industry for the past 30 yr., there must come a sense of victory as they view the accomplishments which have taken place. This has been a victory which, unlike a physical encounter for only temporary supremacy, is as permanent as the human race. We are passing through an age when man is becoming master of materials. Metals made into machinery are used to convert other natural resources into energy available in nearly every home as an unfailing servant.

As we read the paper prepared by Mr. Monroe and published on other pages of this issue, we note how the coal used per kilowatt-hour has decreased from 5.9 lb. in 1900 to 1.52 lb. in 1925; the constantly increasing size of generating units has apparently not reached its limit; the territory served by a single plant is still growing. The plant of today has little resemblance to its forerunner of 30 yr. ago, except as to its coal pile and chimney and even those have changed form with modern coal handling equipment and the use of radial brick and concrete.

In the short space of time during which the central station, as we know it today, has been developing, non-condensing steam engines gave way to condensing engines which in turn have been replaced by steam turbines with mercury turbines as a possible advance; manual handling of coal and ashes has been pushed aside by mechanical equipment; steam pressures have jumped from 100 lb. to 600 lb. in the latest plants, with 1200 lb. being used in pioneering developments; some plants are now working on reheating cycles which a few years ago were thought impracticable.

Then we wonder whether in the field of power generation we are not reaching the point in efficiency beyond which it is uneconomical to go. Possibly so for today but by tomorrow experimental equipment will have been put on a commercial basis and we will be ready for another step forward. Art, literature and music have had their day in the history of man, those masters to whom we are indebted had no way of knowing that their works would be the patterns for generations to come. Scientific engineering, however, is a cumulative art to which all engaged in it may contribute ideas and when the engineer reaches the 100 per cent in converting one form of energy into another, he knows it is time to halt, he does not need to wait even one generation to find out that the peak has been reached in this particular direction.

To gain victory over the forces of nature, as has been done in the past 30 yr., is an accomplishment which would seem well worth the effort of the entire engineering profession.

Getting at the Cause of Our Educational Troubles

For some time, as we have previously pointed out, there has been growing in the consciousness of a certain portion of the American people a vague, half-formed feeling that there is something vitally wrong with the work and product of the American college. The evils of the credit hour plan, student activities, lack of student interest in study and a hundred other symptoms have been noted and discussed by the general public. Engineers and

industrial leaders have complained of the general "wooliness" of the mental processes of two-thirds of our college graduates; they have bewailed his lack of definite preparation, his inability to express himself in his mother tongue, his general uselessness to himself and to anyone else until he has served an apprenticeship in industry as long and as rigorous as that served by the non-college neophyte. Attempts have been and are being made to remedy this situation, by closer co-operation between college and industry. But to every college professor, dean and college president, the real cause of this unsatisfactory situation has been apparent for some time.

This underlying cause is nothing more nor less than the fact that at least one-half of all the students in our American colleges and universities should never have been admitted to college at all, or at least should never be allowed to hope to earn a degree, but should be satisfied with a certificate stating that they had spent a certain amount of time within the halls of learning.

How can such a thing be? In our democratic system is not one man just as good as another, politically, morally and socially? If so, then why is he not entitled to a college education if he can afford one? Simply because, as any college professor will tell you if he dares, unless a man is fitted intellectually, both by inheritance and by preparatory school training, to absorb the things a college is supposed to give him, he ends only by absorbing ideas and information that may do him actual harm and, worse than that, he retards the progress of those students who are better fitted for the college work.

We fail in the college to differentiate between those of preparation and ability above the average and those of only mediocre preparation and ability and we fail to provide different treatment for the two groups so that the second will not retard the progress of the first. Why should a man who passes all his college courses in engineering, for example, with a grade of 70 per cent, receive the same consideration as the man who passes with 97 per cent and wins honors? Surely an engineer must be right more than 70 per cent of the time. The real trouble is that this 70 per center, in undertaking the same work as his fellow student with the 97 per cent capacities, makes it necessary, under our present system, for the higher grade man to sit hour after hour in class rooms listening to elementary explanations of things he has known for days.

When we read the inaugural address of Dr. Parke Rexford Kolbe, on the occasion of his recent induction into the presidency of the Polytechnic Institute of Brooklyn, we were amazed to find the above opinions set forth—amazed that it has apparently become possible for an educator to express in a public address these truths with which every college instructor is familiar but which he seldom dares to utter. We venture to say that nowhere but in an engineering college could he have expressed them.

We agree heartily with Dr. Kolbe's conclusion that the modern college of technology must have, first, the right to choose as entrants only those who are well prepared in the basic preliminary subjects; second, the sympathetic interest of industry in the training of its students and, third, the assurance that its graduates shall have opportunity to continue their mental development and to receive a fair measure of return for their productive efforts. The highest function of the college, however, as Dr. Kolbe states, is the discovery and development of the creative intellect.

Unless we have a few more men with the courage to speak out and face the real cause of the trouble, as has Dr. Kolbe, and unless we heed their words, we see little hope of developing this creative intellect in the best of our college students.

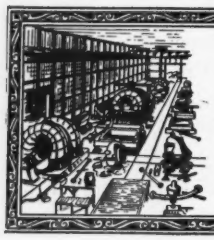
Power and Profits Have Become Dovetailed

At the close of the Civil War, the amount of energy used in all industry and agriculture totaled only slightly in excess of 2,250,000 hp. Today, manufacturing industries, agriculture, mines and the railroads employ an annual amount of energy considerably in excess of 150,000,000 hp. This is an increase of over 1300 per cent, and is perhaps the basic reason why the United States has reached its high level of productivity and efficiency—why individual as well as industrial earnings are so high in comparison with other nations and peoples and why the United States is of so great economic importance.

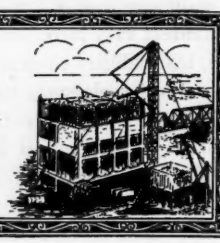
Of the various types of power, electricity has shown the most rapid increase during the last 20 yr. In 1900, less than 1 per cent of the installed power in factories consisted of electric motors. Today, electricity is furnishing 70 per cent of the installed power used in manufacturing plants, the total amount of power used by that branch of industry being well over 35,000,000 hp.

Nor has the development of electricity more than attained a good start. In the coming second-quarter of the present century, electrical development will mount at an increasing rate. Already several enormous projects are under way. At Johnson City, Tennessee, five hydro-electric plants are planned, the largest of the group being the half-million dollar project of the Watauga Power Co. of Elizabethton. These five, however, are but a small part of the development that will soon crystallize in the territory of the Tennessee River. Already definitely conceived is the plan for the building of 100 dams which will have an ultimate aggregate output of 4,000,000 hp. The preliminary survey alone for this tremendous project will cost, it is said, in excess of 500,000 but with its completion there will come about the rapid development of that southern territory which is so rich in coal, iron ore, copper, zinc, limestone, marble, phosphate and timber.

Other projects, equally outstanding in importance, have been planned. Their inception and development only brings home more forcibly the absolute importance of foresight and the realization that our profits for the ensuing 25 yr. will be dependent more upon increased productivity and decreased production costs than on lowered wage scales or cheaper raw materials.



POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS



Electrical Engineers Discuss Many Topics

MIDWINTER CONVENTION OF THE A. I. E. E. BRINGS OUT THIRTY-FIVE PAPERS, DISCLOSING MANY NEW DEVELOPMENTS

DESPITE an unusually heavy snowfall in New York City during the week of February 11, the 14th Annual Midwinter Convention of the American Institute of Electrical Engineers held during that week was well attended and was characterized by the usual excellent program of technical and social events which has always made this convention the one of the year most looked forward to by electrical engineers. The thirty-five papers presented covered the most advanced practice in the electrical art and indicated more clearly than ever the high degree of development this branch of science has attained.

To one who was familiar with last year's program there must have appeared a distinct similarity between the papers presented this year and those presented last year, not alone at the Midwinter meeting but also at the Spring meeting. This aspect of similarity was not imaginary since many of the papers presented at this year's meeting were in a certain sense, continuations or more properly perhaps, outgrowths of some of the papers presented last year. The researches and analytical studies which served as the basis for last year's papers were extended and some of the ideas and suggestions advanced in the discussions last year, were carried out with fruitful results this year.

Take for example the question of system stability. This is a subject which is comparatively new and one which has only made itself manifest since extensive high voltage networks have come into use and since long distance transmission of power has come to the front. This subject was treated in a number of papers last year but since then has been carried to a high degree of refinement as shown by the papers this year. While the problem is by no means solved, either from a theoretical or a practical viewpoint, our knowledge of the conditions involved and our understanding of the nature of the problem itself has certainly been extended.

What has just been stated regarding the problem of system stability can be repeated for the subject of dielectrics and insulation, also an active topic last year. It seems strange that of all the elements which comprise electrical circuits, the one we know the least about is that which makes up the insulation. This year three papers were presented on this subject, one by Professor J. B. Whitehead of Johns Hopkins, one by Professor Karapetoff of Cornell and the third by C. L. Dawes and P. L. Hoover, both of the Harvard Engineering School. Each of these papers approached the problem from a different angle. Professor Whitehead's paper, presented first, was an exhaustive review and comparison of all the various theories of dielectric behavior and dielectric absorption found in the existing literature.

The purpose of Professor Karapetoff's paper was to establish a certain general relationship between, first, the increase in electrical displacement in a solid dielectric and, second, the time after the initial displacement which occurs almost instantly after applying a constant d.c. voltage. Professor Karapetoff, as everyone who has ever heard him knows, has the rare ability to explain complicated phenomena in an understandable manner and this quality was admirably exemplified in the method in which he presented this paper. He made use of an ingenious mechanical analog of an imperfect solid dielectric which indicated what takes place in a solid dielectric when a d.c. voltage is suddenly applied.

C. L. Dawes' and P. L. Hoover's paper which was the final paper in this group, described in detail an extensive series of ionization studies in paper insulated cables. This is a valuable contribution to the art for in this paper, actual test data are given for the first time, showing relations with respect to voltage, power factor, watts, capacitance and temperature in impregnated paper cables.

PROTECTION, CONTROL AND BUS CONSTRUCTION

On Tuesday morning, the second day of the convention, a group of six papers covering protection, control and bus construction were presented. These papers, of particular interest to operating electrical engineers, were received with a great deal of interest. Perhaps the most interesting of this group were the papers by O. R. Schurig and H. P. Keuhni, "Temperature Rise and Losses in Structural-Steel Members Exposed to the Fields from A.C. Conductors" and the one by Titus G. LeClair entitled, "Carrying Capacity of 60-Cycle Busses for Heavy Currents." The first of these two papers gives in detail, the results of an experimental investigation made to obtain practical data on the temperature rises and losses in steel structures in close proximity with conductors carrying heavy currents. This subject has always created considerable discussion, but little experimental data has been available, to test the various theories that have been advanced. One conclusion arrived at in this paper was that the temperature rise in large closed rectangular magnetic frames surrounding a straight conductor, may be calculated separately for each individual beam, disregarding the other three sides of the frame. Short circuited copper loops or bands around iron members crossing at right angles to heavy current carrying conductors may be used effectively to reduce the losses and temperature rise of the iron.

Mr. LeClair's paper on carrying capacity of busses showed that with extremely high currents the usual bus arrangements become inefficient because of unequal distribution of current, and special arrangements are necessary. In a striking example of what happens in busses carrying high currents, the addition of a fifth bar to a bus containing four bars, actually increased the losses and temperature rise for the same current. In the discussion of this paper, Dr. A. E. Kennelly pointed out that in addition to the proximity effect to be considered in bus design, another factor, known as the end current effect must be taken into account.

Another paper of considerable value presented at this Tuesday morning session was the one on "Current-Limiting Reactors with Fireproof Insulation on the Conductors," by F. H. Kierstead of the General Electric Co. Mr. Kierstead illustrated his paper by a series of motion pictures of current-limiting reactors under test which showed the effect of stray iron (bolts, nuts, nails, etc.) drawn into the reactor by its magnetic field. With reactors having thin insulation, the drawing in of this iron invariably resulted in failure of the reactor on short circuit current. When heavy abestos insulation was used on the coils, the entrance of the iron was unaccompanied by serious results.

Electrical Machinery Discussed at Two Sessions

The subject of electrical machinery was presented in two sessions, one on Tuesday afternoon and the second Wednesday morning. Of the eight papers covering this subject only a few can be referred to in this report. Parameters of Heating Curves of Electrical Machinery presented by Professor Karapetoff of Cornell University pointed out that an electrical machine cannot for thermal purposes be considered as a single body. In a rotating machine the stator consists of two metal bodies, between which there may be a temperature difference and the same is true of the rotor. Besides there is a mutual heat flow between the stator and the rotor.

In presenting this paper, Professor Karapetoff stated that it was largely the result of a discussion on Dr. Kennelly's paper on this subject presented in 1924, in which he showed that the heating curve of an electrical machine is an exponential curve, even when the losses themselves are linear functions of the temperature. Professor Karapetoff developed equations similar to those given by Kennelly but included terms for two metal bodies at different temperatures with heat interchange between them through the insulation.

There was considerable discussion on this paper and while all were in agreement as to the correctness of Karapetoff's conclusions regarding an electrical machine as consisting of more than one body, some did not seem to think that the heating was subject to exact calculation. As G. E. Luke of Pittsburgh indicated, an electrical machine must be considered as being composed of innumerable bodies and when an attempt is made to write equations which take into account all these various elements, the job becomes hopeless. He, himself, had calculated machines using formulas similar to Karapetoff's but with terms for three bodies, and while he did finally succeed in arriving at certain results, when he tried to get other engineers to use these formulas, he met with failure. "The equations look good," they said, "but you work out the problem."

C. J. Fechheimer's paper, on the rating of electrical machinery as affected by altitude, pointed out that the rules of the A. I. E. E. Standards Committee are inadequate in rating machines with respect to altitude. He proposed equations to show how temperature rise increases with elevation and advocated a change in the standards so as to govern, more accurately than they do now, temperature rise as affected by changes in altitude.

In another paper, "Starting Characteristics of Polyphase Squirrel-cage Induction Motors and Their Control," by H. M. Norman of the Westinghouse Electric & Mfg. Co., there was discussed, the characteristics of squirrel-cage induction motors during starting, stopping and reversing. Equations were given which allowed a comparison to be made between loss of time and acceleration. These equations should prove useful in determining the best value of secondary resistance for a certain application.

Electromagnetism and Physics

The papers presented at the session devoted to Electromagnetism and Physics on Thursday morning were not of a type to invoke heated discussion among a group of operating engineers, but to those who sometimes sit down and think and wonder what electricity and magnetism is, what this business of electrical engineering is all about, this group of papers held considerable interest. The professors of electrical engineering, of whom there were quite a number present, came into their own at this session.

Four papers were presented, but the one of greatest interest, was the one by Carl Hering on the Properties of the Single Conductor. Dr. Hering, it must be remembered is the iconoclast of the Institute. He is the smasher of idols, the disillusionist who for a number of years past has attacked many of the postulates in classical electromagnetic theory. He has no use for infinities, and claims that a too promiscuous use of the term infinity has led electrical engineers into many pitfalls. In this paper, he discussed the properties of a unit length of single straight conductor far removed from all other circuits. He deduced a constant for the energy stored by a current in such a unit length of wire, which seems to be one of the most fundamental constants in electrodynamics, and one from which many important deductions can be made. This energy corresponds to the $mv^2/2$ of a moving mass.

Needless to state, this paper created some interesting discussion, mostly in disagreement but interesting nevertheless. As usual in discussions of Dr. Hering's papers, it was held that his entire neglect of an infinite number of infinitesimal quantities had led him to absolutely erroneous conclusions.

Dr. Hering, however, is never disconcerted by such discussion, in fact he invites it, and has much experimental evidence at hand to substantiate his theories. Regardless of whether it is right or wrong, he is greatly to be admired for his courage in attacking that which he believes to be wrong.

The final technical session was held on Thursday afternoon, at which a group of papers were presented covering Instruments, Machinery and Industrial applications of electricity.

If any one thing about the various technical sessions impressed the attending numbers more than other things it was probably the abstruse character of the papers. This has been the case with other meetings during the last few years. Most of the papers are mathematical in nature and reflect to an unusual degree the high intelligence of the modern electrical engineer. Everything in the art, it seems

is subject to rigid calculation and mathematical analysis. In presenting his paper on Parameters of Heating Curves of Electrical Machinery, Professor Karapetoff suggested in fact, that it would be possible to do away entirely with expensive heat run tests of large alternators, substituting instead a program of rigid calculation by which to determine the same results.

Another unusual event, although by no means new, was the presentation of a paper on the Practical Aspects of System Stability, by Miss Edith Clarke. If there are more women who have the ability to develop such ingenious methods of analysis, as Miss Clarke developed for determining stability in an electrical network, they certainly will be welcomed by the Institute.

Inspection Visits

Although the heavy snowfall in New York at the time of the convention made it necessary to cancel several of the more important inspection visits on the program, there were nevertheless sufficient trips available to satisfy the desires of everybody. Among the more important trips taken were the visits to the Bell Telephone Laboratories, the Holland Tunnel, Hell Gate Power Station and the Central Machine Switching office of the New York Telephone Co.

Social Events

Many social events marked the program. On Tuesday night there was a Smoker at the Hotel Astor and on Wednesday evening, the Annual Dinner Dance was held at the same hotel.

Perhaps the most interesting of all social events, however, were the lectures on Thursday evening by Dr. Alexis Carrel of the Rockefeller Institute for Medical Research, and by Major Allen Carpe of the American Alpine Club.

Dr. Carrel, who it will be known is the world famous biologist, gave an illustrated talk on modern developments of biological research. His talk, intensely interesting dealt particularly with the life of tissues outside of the organism, and was accompanied by motion pictures showing the actual growth of living cells. Some strains of cells in Dr. Carrel's laboratory have been living and growing under artificial conditions since 1912.

Major Carpe, described by word and motion pictures, "The Ascent of Mount Logan," the highest peak in Canada and probably the largest mountain mass in the world. Major Carpe, a member of the Institute, is also a fellow of the Royal Geographic Society and when not mountain climbing devotes his time to electrical engineering.

Ammeter, Voltmeter and Ohmmeter in One Instrument

For purposes of testing batteries, for checking voltage, for measuring insulation and in making load tests, a new little instrument recently placed on the market by the Electrical Engineering Service of New York City should be extremely handy. This device, known as the AVO tester is a combination ammeter, voltmeter and ohmmeter. It is small, only 7 by 3 by 1½ in., easily carried in the pocket and is accurate enough for the majority of tests. It is, however, not a precision instrument for accurate efficiency measurements.

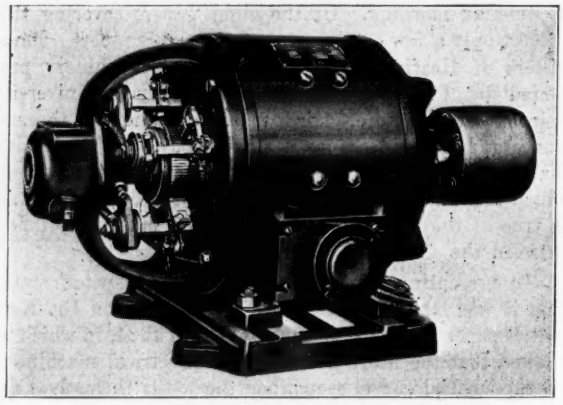
It has a d'Arsonval element which makes possible a scale with even divisions for voltage and current measurements. Actually, the instrument is a millivoltmeter with a 200 mv. full scale. A shunt for a 10-ampere scale is supplied with the meter but any shunt for higher readings may be furnished. For voltage readings series resistances are built into the instrument. For use in measuring resistance, an ordinary flat flashlight battery of commercial 4.5-v. size is held in the case by a removable spring. As only a low current is used for resistance measurements and with an adjustment for voltage drop, the battery will last a long time.

Scales used are as follows:

Voltmeter scales; 5 v. to 50 v.—250 v. ammeter scales; without shunt up to 1 amp. with shunt, 10 amp. scale. Other shunts can be supplied. Millivoltmeter scale; 200 millivolts, full scale. Ohmmeter scale; 500,000 ohms.

Louis Allis Direct-Current Motors

In the accompanying illustration is shown a photographic view of one of the new direct-current motors recently developed and placed on the market by the Louis Allis Co. of Milwaukee, Wis. This is one of a series known as their type N. A. motors, having a 40 deg. rating and heavy overload capacity. They are general purpose motors and are interchangeable, rating for rating, in all essential dimensions with the Louis Allis polyphase motors.



TYPE N. A. LOUIS ALLIS D.C. MOTOR

Improved design and ventilation insures uniform cooling throughout the windings and makes an unusually cool motor under operation. The bearing chamber is designed to hold an extra quantity of oil, making frequent renewals of oil supply unnecessary. The bearing inspection opening is closed by a removable cover. This metal cover, while permitting easy inspection, gives in effect a dust tight bearing chamber.

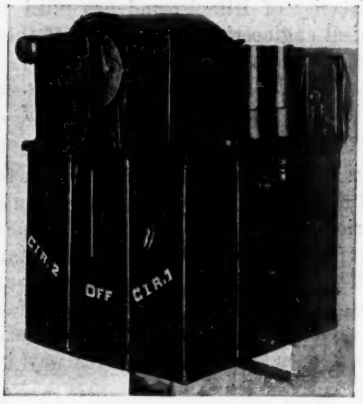
Power Developments in the Mississippi Valley

In the article under this title published in the February 15 issue, an unfortunate typographical error appears. On page 253, second column, fourteenth and fifteenth lines, the figure of 83,000,000 t. of coal should have been 93,000,000 t. In order to prevent error when using this figure in future calculations, we would suggest that readers make this correction in their copies while it is still in mind.

Automatic Change-Over Switch Insures Continuity of Service

AN AUTOMATIC Change-Over Switch that has for its chief application installations where continuity of service is the primary feature and where interconnected secondaries are not available, has been designed and is being manufactured by the Westinghouse Electric and Manufacturing Co. It has a full automatic feature which functions to keep the main contacts on a predetermined circuit as long as that circuit is energized and which assures the operator that his feeder loads are properly distributed under normal conditions. Another feature of this switch is that by opening a single-throw knife-switch the main contacts can be thrown from the preferred to the auxiliary circuit and by closing the knife-switch the main contacts will be returned to the preferred circuit.

This Automatic Change-Over Switch depends for its operation on the action of an undervoltage release coil. The wiring is such that when the voltage fails in the preferred circuit, the low-voltage plunger will fall. This completes the circuit from the instrument transformer on the auxiliary circuit through the drum switch on the shaft of the operating mechanism to the trip coil. The trip coil raises its plunger and allows the main drum to revolve through an arc of 180 deg. This throws the main contacts of the breaker from the preferred circuit to the auxiliary circuit.



NEW CHANGE-OVER SWITCH ASSEMBLED IN TANK WITH COVER IN PLACE

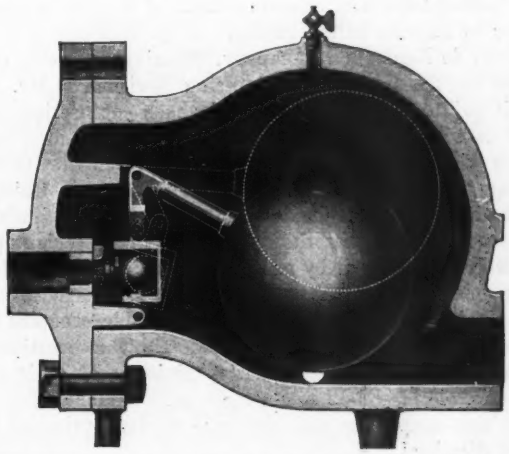
The main contacts of the switch remain on the auxiliary circuit until the service voltage is restored to the preferred circuit. When energy is restored to the preferred circuit, the low-voltage release raises its plunger, thus breaking contact. The trip coil is then energized from transformer through the drum switch and again raises the plunger, which allows the drum to revolve through 180 deg. Thus, the main contacts of the switch are returned to the preferred circuit.

In construction this switch, which is essentially a three-pole, double throw, full automatic oil circuit breaker, with a low voltage release attachment, is sturdy and compact. The oil tank is lined with micarta, while the tubes of the same material protect all incoming and outgoing terminals. The main contacts are of the familiar wedge and flexible finger type and the operating drum, mounted directly above the oil tank, is protected by a dust-proof cover through which a shaft extends.

Float Actuates Ball Seat Steam Trap

IN THE ACCOMPANYING illustration is shown a ball seat steam trap recently placed on the market. It has few parts and has but two positions: completely shut and wide open. It was designed and developed by a practical steam engineer expressly to overcome the troubles that he had experienced in his own plant. The trap is now being manufactured and marketed by the Williams Gauge Co., Pittsburgh, Pa., and is known as the "Williams New Ball Seat Trap No 4B."

The ball valve of this trap is designed to be absolutely closed and leakless when the float is in the position shown



WHEN FLOAT IS DOWN, BALL IS HELD AGAINST SEAT. DOTTED LINES SHOW OPEN POSITION

in the accompanying cross-sectional photograph. The float is made of welded chrome nickel, tested at 600 to 1200 lb. per sq. in.

As the water in the chamber rises, the float, of course, rises also but the trap does not open immediately. The designer purposely made an amply large cage for holding the ball so that there is about ⅛-in. "lost motion" or "play" between the ball valve and its cage; therefore the ball is held in place by the pressure in the trap body until the float rises to the position shown dotted. When the float is in that position, the cage finally pulls the ball away from its seat.

As soon as the ball leaves its seat, the pressure is equalized and the ball moves to the back of the cage, as shown in its dotted position, leaving the outlet wide open so that the discharge is quickly accomplished. As the water discharges, the float lowers again and when the water has reached a point 3 or 4 in. above the outlet the float is back to its initial position as shown in the photograph. This action of the float tips the cage forward to a point where the ball is caught by the water being discharged and the valve closes with a snap. Ball and seat fit accurately, are both made of monel metal and are removable and easily renewable.

ANNOUNCEMENT has been made by the East Texas Public Service Co. that it has purchased the Home Light & Ice Co. of Pittsburgh, Camp County, Texas. This company serves Pittsburgh, Leesburg and Newson with electric service and ice and serves Daingerfield with ice.

A. S. S. E. Holds Fourth Midwest Conference

ON JANUARY 18 the fourth annual Midwest Safety Conference of the American Society of Safety Engineers—Engineering Section, National Safety Council, in co-operation with the recently organized Chicago Safety Council, was held at the Hotel La Salle, Chicago. Sessions were attended by about 400 leaders in safety work through middle western states.

The morning session opened with a practical demonstration, staged by the Chicago, North Shore and Milwaukee Railroad, of a shop safety committee in action, hearing reports, making plans and receiving the admonitions and encouragement of a plant manager eager to improve safety results. L. A. DeBlois, of E. I. duPont de Nemours & Company, Wilmington, Dela., then spoke on the subject, "Engineering Revision." Mr. DeBlois pointed out that it is only by such engineering revision as will completely remove the hazard that most accidents which take place today may be prevented. George Hodge, of the International Harvester Company, Chicago, spoke on the "Educational Value of Safety Organization." He was insistent that the responsibility for accident prevention be passed on by management directly to the foreman on the job.

An interesting and helpful round table occupied the latter part of the afternoon session. The question of goggles developed the emphatic opinion that their continuous use must be made a rigid part of plant rules and that non-compliance with this rule merits reprimand and final dismissal.

G. T. Hellmuth, of the Chicago, North Shore & Milwaukee Railroad, was chairman of the evening dinner session, and C. B. Scott, president of the National Safety Council, acted as toastmaster. Evening speakers were R. F. Johnstone, president of the Chicago Safety Council, Judson G. Rosebush, president of the Patten Paper Company, Appleton, Wis., and Judge Alva R. Corlett, of Cleveland, Ohio.

News Notes

AT A MEETING of the Board of Directors of the American Institute of Steel Construction held in New York on Friday, January 22, a decision was made to proceed with the publication of a sales manual, as recommended in the recent report of the committee on improvement in selling methods, submitted to the annual convention. A corps of field engineers will be organized and a department of architectural relations will be organized. Larger office facilities have been obtained in the new Murray Hill Building, 285 Madison Ave., New York, corner of 40th St., which will be occupied about February 20. A. T. North, member American Institute of Architects, and until recently associate editor of "The American Architect," will prepare the sales manual and have charge of the Department of Architectural Relations.

THE NEW ENGLAND REGIONAL meeting of the American Society of Mechanical Engineers will be held May 3 to 6 inclusive in Providence, with headquarters at the Providence Biltmore Hotel, when upwards of a thousand delegates are expected to be present. In addition to New England members, delegates are expected from many other states. Included among the guests will be the president and members of the National council will also be present. Included in the projects to be discussed are machine shop practice, industrial power, wood industry, petroleum, central station power and textiles. All of the large industrial plants in Providence and vicinity will be visited and a trip has been arranged to the Newport Torpedo Station.

L. D. Burlingame is general chairman of the committee in charge and Norman L. Sammis is secretary. F. C. Freeman heads the finance committee; Professor J. A. Hall the technical events, Eugene W. O'Brien the printing, Warren B. Lewis the hotel, Samuel D. Fitzsimmons the excursions, William A. Kennedy the information, Professor W. H. Kenerson the publicity, John R. Freeman the reception, Mrs. Henry D. Sharpe the ladies, and President A. E. Thornley of the Providence Engineering Society the members-at-large committees arranging the programs, each with a corps of able assistants.

AT THE ANNUAL meeting, the following officers of Engineering Foundation were elected: Chairman, Lewis B. Stilwell of the A. I. E. E.; vice-chairmen, Elmer A. Sperry of the A. I. E. E., and George A. Orrok of the A. S. M. E.; members of executive committee, J. Vipond Davies of the A. I. M. E. and Arthur M. Greene, Jr., of the A. S. M. E.; director and secretary, Alfred D. Flinn; treasurer, Jacob S. Langthorn; assistant treasurer, Henry A. Lardner.

THE RILEY STOKER CORP. has recently appointed Ollison Craig as consulting engineer. Mr. Craig is a graduate of the University of Illinois, and has filled positions in the mechanical engineering departments of the University of Colorado, Vanderbilt University and Iowa State College. He has also been associated with Chas. L. Pillsbury Co. and with the Underfeed Stoker Co. of America as research engineer.

COL. WILLIAM KELLY of New York City, former chief engineer of the Federal Power Committee, gave a talk on hydro-electric power development in Maine from the standpoint of an outsider at the Portland Rotary luncheon recently. This was in connection with the campaign to pass a general law permitting the export of power from Maine, at present prohibited by state law except in the case of the Cooper development under way in Passamaquoddy Bay.

STONE & WEBSTER, INC., of Boston will erect a building of its own, in which its offices and departments will be located, at Water and Kilby Streets, Boston. The structure will be 14 stories high, with 175 ft. frontage on Water St. and 60 ft. on Kilby St. Stone & Webster's present main offices are at 147 Milk St. and other office space in several other buildings is required.

J. F. LINCOLN, vice-president of the Lincoln Electric Co., is making a six weeks' trip to visit distributors and address technical societies. He will cover New York, North Carolina, New Orleans, Texas, Oklahoma City, Phoenix, the Pacific Coast cities, Duluth, Kansas City and Chicago.

THE FRANKLIN INSTITUTE has recently awarded the John Price Wetherill Medal to the Wagner Electric Co. of St. Louis, Mo., with special mention of Val A. Fynn and Hans Weichsel in connection with the progress in electric art, which the invention of the Fynn-Weichsel motor marks and of the development of a motor of excellent design and construction. A Fynn-Weichsel motor is of the

synchronous induction type, either 2 or 3 phase, having an automatic self-generated direct current to obtain the synchronous speed but with characteristics quite different from the ordinary synchronous motor. It may be used to produce mechanical power at unity power factor or it may produce and also raise the power factor of other motors in the same installation.

LEWIS GOLDBERG of Boston has been appointed by Gov. Alvan T. Fuller as chairman of the Public Utilities Commission of the state, succeeding David A. Ellis, resigned.

ON FEBRUARY 1 the Celite Products Co. moved its San Francisco Office from the Monadnock Building to 140 Spear St., in order to provide larger quarters and better operating facilities.

THE DEARBORN CHEMICAL Co. announces that Paul T. Payne; district sales manager with headquarters at Indianapolis, Ind., has been given jurisdiction over the office at Birmingham, Ala., and at Atlanta, Ga.

MILTON J. WARNER has been added to the directorate of the New Haven Trust Co. at New Haven, Conn. Mr. Warner is general manager of the Rockville-Willimantic Lighting Co. and is a director of other corporations.

THE NEW ENGLAND PUBLIC SERVICE Co., a subsidiary of the Middlewest Utilities Co. of the Insull interests, acquired the Souhegan Valley Electric Co. at Milford, N. H., Feb. 15.

AT A MEETING of the board of directors of the Chicago Fuse Mfg. Co., held February 15, A. E. Tregenza, who has been assistant to the president, William W. Merrell, was appointed vice-president in charge of sales.

THE BERNITZ FURNACE APPLIANCE Co., Boston, Mass., has recently added E. G. Schlayer to its organization as sales and service engineer. Mr. Schlayer was formerly connected with the Connecticut Co. at Hartford, Conn., as combustion engineer.

ANNOUNCEMENT is made by the Bundy Steam Trap Co. that William S. Corcoran, 29 North Second St., Harrisburg, Pa., and the Steam Economy Co., Indianapolis, Ind., has been appointed agent in their respective territories for equipment manufactured by the Bundy Steam Trap Co.

THE SAN ANTONIO PUBLIC SERVICE Co., San Antonio, Tex., is installing two 1000-hp. Heine V-type boilers, which will be fired by gas and oil and operated at 300 per cent rating. This work is being done under the supervision of George A. Smith, assistant superintendent of the company.

MAX TOLTZ of St. Paul, Minn., has recently been given the honorary degree of Doctor of Engineering by the Ramsey Institute of Technology in recognition of high standing in the consulting engineering profession and outstanding achievements in the design of power plants and industrial buildings.

FIN TYPE SURFACE air coolers with hydro-electric generators will be used for the first time in connection with the new station which is being built by the Louisville Hydroelectric Co., just above Louisville, Ky., on the Ohio River. Because of the use of soft coal in the city and the consequent trouble which would be caused if open ventilation of equipment were used, it has been decided that the closed system of ventilation would be preferable. The major use of surface air coolers has been with turbine-generator equipments. The generating equipment of the new station will include eight 10,000-kv.a., 14,000-v., 100-r.p.m. hydroelectric generators, each equipped with fin type surface air coolers. Both the generators and coolers will be supplied by the General Electric Co. The development is being made at the site of one of the state-built navigation dams. According to the season, the head varies to a maximum of 40 ft. The power developed there will be used in and around Louisville.

FREDERICK A. HUNTRESS, general manager of the Brazilian Traction, Light & Power Co. of Rio de Janeiro, and actively identified with power, telephone and gas companies in South America as well as traction and power companies in New England, died January 27 at Hotel Somerset, Boston, Mass.

WILLIAM K. VANDERPOEL, since January 1, 1916, General Superintendent of Distribution, of what is now the Electric Department of Public Service Electric and Gas Co., has resigned to become Vice-President and Executive Engineer of the Okonite Co. and the Okonite-Callender Cable Co., Inc., with factories at Paterson and Passaic and general offices in New York City.

THE DETROIT EDISON Co. recently placed an order with the American Engineering Co. of Philadelphia for six Taylor underfeed stokers for an addition to its Marysville plant. Each stoker will have 24 retorts, 21 tuyeres long, with deep ashpits and clinker grinders. The six stokers will serve three boilers, each having 28,210 sq. ft. of heating surface or a total of 8463 b.hp.

THE READING IRON Co. of Reading, Pa., has recently appointed R. M. Thomas and Donald Charlton as technical representatives. The technical department of the company has recently been created as a service division to the sales department. This department will be required to give technical and practical counsel to customers having pipe, bolt and boiler tube troubles.

F. H. PENBERTHY, former manager of the Kansas City district territory for the Elliott Co., died on January 29, death being caused from sinus trouble. Mr. Penberthy opened up the Kansas City district office for the company in 1918. He had lived in Kansas City the greater part of his life, although he attended the Colorado School of Mines at Boulder, from which he received a degree of Mechanical Engineer.

L. S. PLAUT & Co., Newark, N. J., has just put into operation a power plant, designed to meet the needs of its new department store. Steam is generated by four 300-hp. Heine boilers equipped with mechanical oil burners, installed by the Engineer Co. and using the Merritt system of steam control. A 12-t. York compressor is in operation and the second machine is to be installed in the near future for refrigerating purposes.

ONE OF the first installations in this country of an oil engine supplied with scavenging air from a separate, direct current, motor-driven centrifugal air compressor, is in the Trommers Brewery, Brooklyn, N. Y. The oil engine drives a generator and is of the Knudsen Diesel type. The compressor is a General Electric machine, rated 1400 cu. ft. per min., 2½ lb. pressure, 3500 r.p.m., and is driven by a 115-v., d.c. motor. Scavenging air is furnished for the purpose of removing the foul gases from the cylinders of the oil engine, this work formerly being done by air supplied from an additional piston on the oil engine. By using the centrifugal compressor, a total re-

duction in weight of approximately 5 per cent and a 12 per cent reduction in length are effected. Smoothing out the pulsations in the supply of scavenging air is another advantage of the centrifugal unit. The discharge pressure is easily varied by adjusting the speed of the direct motor which drives the compressor. This is done by controlling the field of the motor.

THE WESTERN FLOUR MILLS, Davenport, Iowa, is completing the work of installing a new 300-hp. Connelly water tube boiler equipped with Sturtevant superheater. Strong Scott pulverizers will also be installed to prepare fuel for the present boiler installation as well as the new boiler. Coal will be handled by a Stevens-Adamson hoist. This work is being done under the supervision of F. E. Stoneburner, chief engineer of the flour mills.

ANNOUNCEMENT has recently been made that a merger has been effected of the Hewitt Rubber Co. of Buffalo, N. Y., and the Gutta Percha & Rubber Mfg. Co. of New York and Brooklyn. At a reorganization meeting held recently, F. E. Miller was elected president of the Gutta Percha & Rubber Mfg. Co., John H. Kelly and Amadee Spadone were elected vice presidents and W. J. Magree, secretary and treasurer. The reorganization is the first step in the removal of the company's plant, office and other facilities to Buffalo.

THE HYDROELECTRIC POWER COMMISSION, Toronto, Ont., has received authority from the provincial government to proceed with a proposed hydroelectric power development at the Alexander Falls, on the Nipigon River, supplementing its other similar plants in this section. The new station will have a rated capacity of 50,000 hp. and will make a total of 115,000 hp. for the Government's development in the Thunder Bay district. The plant is estimated to cost $7,000,000, with transmission system, and is slated to be ready for service early in 1928. This will make a total investment of $18,000,000, which has been expended by the Government in power projects here.

Catalog Notes

THE AMERICAN ENGINEERING CO., of Philadelphia, Pa., has recently issued a catalog describing Juruick ammonia compressors which are made in capacities ranging from 2 t. to 25 t. and can be installed for hand or automatic control. The catalog is well illustrated to aid in the description of the details of construction.

THE INTERNATIONAL NICKEL CO., 69 Wall St., New York, has recently issued two pamphlets designated as Nickel Steel Data and Applications No. 1 and No. 2, which contain information on the properties and specifications for steels as used by the automotive industries and the physical and mechanical properties of nickel steels as described by the Bureau of Standards.

FLEXIBLE FIXTURE hangers are described in the folder, recently issued by Crouse-Hinds Co. of Syracuse, N. Y. These hangers are particularly applicable for factory lighting.

THE COCHRANE BULLETIN for December, 1925, which is published by the Cochrane Corp., Philadelphia, Pa., deals with vent-condensers and their uses and describes a vent condenser as a small surface heater connected in the vent line from an open vent water heater, deaerating heater, hot process water softener or vent heater. They are used to reclaim the heat which ordinarily passes to the atmosphere through the vent and are also useful where the heater is operated below atmospheric pressure, necessitating an air pump to exhaust the non-condensible gases.

WILSON-SNYDER CO., Pittsburgh, Pa., has recently issued a folder describing the long stroke Wilson-Snyder oil pump, which has met with considerable success in the handling of oils for industrial purposes.

GRANT GEAR WORKS, Boston, Mass., has just issued its 1926 catalog dealing with worm gear reduction units. This is a handy pocket-size catalog, filled with tables and illustrations, which are a ready help to the engineer in selecting his gears.

THE "LATERAL RETORT" underfeed stoker is described in a 24-page catalog, recently issued by the Riley Stoker Corp., of Worcester, Mass. This catalog is well illustrated with halftones and line drawings and the text matter deals with the construction, operation and specific installations of this stoker.

"AUTOMATIC SWITCHING EQUIPMENT," is the title of a 23-page bulletin just issued by the General Electric Co. and bearing the number GEA-295. The bulletin illustrates and describes the application of automatic switching equipment to railway service, hydro-electric generators, mining and industrial service, central station service, etc.

A. M. BYERS CO., Pittsburgh, Pa., is distributing a pamphlet containing a story entitled "The Little Red Ball and the Story of Good Wrought Iron," which was written by Donald Wilhelm, and carries the reader in thought through a modern pipe mill, pointing out the various characteristics of piping and how difficulties have been solved by the manufacturer.

THE HARDINGE CO., York, Pa., has recently issued Catalog 13-A under the title of "Hardinge Conical Mills," which describes conical ball and pebble mills and their application to the field of grinding and pulverizing. The catalog not only describes the Hardinge mills but gives the classification of grinding operations, the theory of grinding and the application of grinders to various industries.

AN INDUSTRIAL CONTROL CATALOG has been issued by the General Electric Co., bearing the number GEA-257. This publication furnishes information on representative lines of industrial control manufactured by that company and includes a reprint of the industrial control section of the company's general catalog; instructive matter on the care and operation of control devices; wiring diagrams of some standard controllers, push buttons and other accessories; reference tables; lists of publications and other useful information. It has 160 pages, and is bound in paper.

A. M. BYERS CO. of Pittsburgh, Pa., has brought out a new four-reel film, a Pathe production entitled "The Little Red Ball." It embodies a diagrammatic as well as a scenic presentation of the manufacture of wrought iron pipe from ore to finished product. Especially interesting are the parts showing the hand puddling of genuine wrought iron, including diagrammatic views of the interior of a puddling furnace, the drawing of the "little red ball," squeezing, rolling of muck bar, cutting, piling, re-heating, and rolling, which are characteristic of wrought iron processes. The methods of forming and welding flat strips of "skelp" into pipe are especially well explained by animated drawings. This film is available to engineering, trade and business clubs and organizations generally.

Sparks from the Advertising Pages

Where Buyers and Sellers Meet

Upholding the Arms of Power Plant Men

Between inert fuel and the seemingly magically created energy of mechanical power that serves, unseen, all about us, is the mighty realm of power plant men.

Since the first practical application of steam power to useful work, thousands of horsepower have been added to thousands; then millions to millions, until today the total mechanical power alone is greater than all the man-power and all the physical horsepower that ever existed in the world.

Where the minds of power plant men meet, in face to face contact or through the printed page, more is accomplished for the growth of a nation and the life of a people than where men meet in world courts.

To these masters of power which is back of modern civilization, this publication is dedicated.

In it will be found the perfected products that make possible the generation of mechanical power, for to know how to do a thing it is necessary to know what to do it with.

Time has sifted the products shown here; service has proved them, and they have kept ahead in the strenuous competition with unknown hosts of other products.

Unlimited research, ceaseless vigilance and the careful consideration of the best minds in the power plant field contribute to the perfection and application of these products.

As each product is applied to a specific purpose, each application points the way to further applications. Each step in the development of each product and its application calls for other and improved products.

Widening vistas of opportunity beckon every man who has to do with power generation.

Who shall welcome such opportunities; who shall profit by them, depends predominantly on the extent and rapidity with which these products are employed.

By this token, study every advertisement in the issue. Take advantage of every available contact with the men responsible for the products shown here. Give consideration to and act on their offers of information and assistance.

More rapid advance in plant and personal efficiency awaits those who take advantage of the inventive genius, the years of experience and successful engineering which progressive firms here offer freely for you to draw upon.

Detroit Edison
Taylor

On February 4th the Detroit Edison Co. placed its order for Taylor Stokers for the service of 8463 rated B.h.p., in a new extension to its Marysville central power station.

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